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A STUDY OF THE PRELIMINARY BUILDING DESIGN STAGE

A THESIS

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The Faculty of the Graduate Division

by

Carter Nelson Williams, IV

In Partial Fulfillment

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SUMMARY

The objective of the thesis is to investigate the decisions made and the process followed in the preliminary stages of building design. The method of attack is to generalize from past experience. First a building will be designed and the decisions made for a building design will be generalized. This cycle will be repeated in hopes of reaching a conclusion.

The conclusions reached are as follows:

1. The terms used to describe the design process must be precisely defined in order to understand the process.

2. For every building, there exists a set of Requirements which must be satisfied.

3. The Requirements of a building result from three sources:

   A. The function of the building.

   B. The constraints of the particular problem.

   C. The method to accomplish a Goal. These Requirements are established subjectively.

4. It is not possible to determine if some Requirements are satisfied until the detail design stage. The amount of time required to check them limits their usefulness in the preliminary design stage.

5. An optimum solution depends upon the accomplishment of the Goals. But what constitutes the accomplishment of a Goal is subject to interpretation.

6. A method to accomplish a Goal becomes a Requirement when there

is only a single method to accomplish it.

7. In the preliminary design stage, the Goals present two difficulties, the difficulty of determining the importance of accomplishing a certain Goal and the difficulty of determining the degree of accomplishing a Goal.

8. The Goals in which the methods to accomplish them can be readily compared play a more important part in the preliminary design stage than the Goals in which the methods to accomplish them cannot be readily compared.

9. The necessary decisions in the preliminary design stage are:

A. The first decision is to decide if enough Requirements have been established to insure that building will function within the constraints of the problem.

B. Next a number of Concept Decisions are made. The Concept Decisions produce a series of bounds on the solution which are at first very wide, encompassing many possible design concepts, but as more decisions are made the bounds become increasingly narrow until the design concept is reached and the preliminary design stage is complete. Each Concept Decision is a series of three decisions:

1. The selection of alternative solutions.

2. The determination of whether enough alternatives are proposed.

3. The decision among the alternatives to determine a bound on the solution. This involves two steps.

a. Each alternative is examined to determine if it is satisfied by all the Requirements.

b. How well each alternative accomplishes the Goals is compared to how well every other one accomplishes them.

10. Only if the structural form has not already been well established, then the Theory of Structures plays an important part in deciding among alternatives and establishing the design concept.

CHAPTER I

INTRODUCTION

The design of a building can be divided into two stages, the preliminary design stage and the detail design stage.* In the first, the concept of the building is originated; in the second, the details necessary to make the concept constructable are worked out.

The preliminary design stage has two functions, to establish the requirements and goals or objectives for the building, and to originate the design concept for the building. A requirement is a physical necessity for the building. It is essentail to the building and is either satisfied or not. There is no degree of satisfying a requirement. A goal or objective is a characteristic desired in the building. These are striven for in the building, but they are not indispensable. The goals can be accomplished to a varying degree.

The design concept is the solution which is the output of the preliminary design stage. A solution to the design problem is a plan which describes a building that satisfies all the requirements and accomplishes any number of the goals to any degree. It should be noted that the set of requirements may be such that they determine a unique solution or eliminate the possibility of a solution. But this is not generally the case.

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* The exact meaning of the terms used to describe the building design process is very important to the description. Various authors give different meaning to the same term. In this paper, therefore, terms which have special meaning will be underlined when they first appear and defined in the glossary in Appendix I.

A solution is obtained by combining discrete schemes of the parameters and variables of the building. A parameter is a physical element that may assume different schemes during design only, but is constant after construction. A variable is a physical element that may assume different schemes at any time, either during the design or after construction.

Besides the parameters and variables of the building, each problem has constraints which make the problem distinct. A constraint is a physical element that is not subject to change at any time.

The objective of the thesis is to investigate the decisions made and the process followed in the preliminary stages of building design. The method of attack is to generalize from past experience. First a building will be designed and the decisions made for a building design will be generalized. This cycle will be repeated in hopes of reaching a conclusion.

CHAPTER II

REVIEW OF PREVIOUS WORK

There are several differing theories about the process by which design is accomplished. A review of several current interpretations will be presented.

Thomas T. Woodson in Introduction to Engineering Design defines design as "an iterative decision-making activity to produce the plans by which resources are converted, preferably optimally, into systems or devices to meet human needs." (1) In other words, design is a decision-making process which is repeated a number of times. The object of this repeated process is to produce plans to convert, in the best possible way, the materials available into a physical solution to human needs.

The details of Woodson's Design Structure is divided into four phases in this order: the Feasibility Study to validate the need and produce a set of possible solutions, the Preliminary Design to quantify the parameters in order to yield the optimum solution, the Detail Design to reduce the best solution to a description for construction, and Revision to produce an improved or acceptable design (2). The research of this paper will be limited to the area in which the concept of the building is determined. This area corresponds to the Feasibility Study and the first step of the Preliminary Design as presented by Woodson. In the introduction, this area is called the preliminary stage of building design.

The repeated graphic module in the Design Structure is the "iterative decision-making activity" mentioned in Woodson's definition of design. He names this the "Design Process." (3) This process is shown in Figure 1, and is used to transform the input information into output information which is used in the next step. This process, which is the essential feature of the Design Structure, performs an organization and evaluation of information. Woodson does not explain how this is achieved.

The idea of optimization mentioned in Woodson's definition of design is predicated on the assumption that mathematical cause and effect relationships are known (4). Also he assumes that the engineer "knows enough about the field to choose correctly his primitive form or shape in accordance with the fundamental principles at work" so optimization can proceed (5). This brings up many questions in relation to building design. How is the initial configuration determined? What are the fundamental principles that set this configuration? Should Structural Theory set it, or should the function of the building set it? Should an aesthetic consideration set this configuration, or should the principles governing the environmental control set it? Should all of these and more be combined to set this configuration; if so, how should they be combined? Also, time is an important element. How much time should be spent in determining the initial configuration? These are only a few of the questions that arise before the initial configuration can be determined. The purpose of this paper is to investigate how the initial configuration of a building is determined.

In contrast to Woodson, Alger and Hays in their book, Creative Synthesis in Design, do not define design but rather state that it is

helpful to use a plan for carrying out design work. The plan is called the "Design Process", and is "a series of steps or stages through which any design will pass before it is completed." (6) The rest of their book is devoted to developing the six stages of the "Design Process", which are given in Figure 2. The first step, Recognizing, consists of determining if a real problem exists and, if so, what it is (7). The next step produces the detailed specifications which must be met (8). The third step, the most challenging one, produces a series of alternative solutions to meet the specifications (9). These are evaluated in the fourth step. Based on the evaluations, the decision on a solution is made in the fifth step. Finally, the details are worked out to implement the chosen solution.

These six steps in the design process greatly over-simplify the problem of design. An orderly step by step application is impossible in actual practice. In fact, each succeeding step helps to clarigy the preceding steps. Investigating the performance possibilities, for example, will help specify fully the performance goals. These steps are interlinked and dependent on one another. In a similar manner, evaluating alternatives usually leads to improvements or entirely new concepts (10).

There are uaually many possible designs which can be used to perform a given function, and it is difficult to decide among the alternatives. In their "Decision Table," (11) Alger and Hays present a systematic method for evaluating the alternatives. This table clearly lays out all the attributes of each alternative in order to compare how well each might satisfy the specifications. A generalized form of a "Decision Table" is shown in Figure 3. Because no alternative

usually meets all the specifications completely, deciding on a solution involves weighing the importance of the various specifications of the alternatives.

Whereas Woodson ignores completely the origin of the alternatives, Alger and Hays attribute them to the "creativity" of the designer. They define creativity as "a measure of the choice made in reaching the solution to a problem," and give their ideas on how to improve creativity. It should be noted that they avoid describing how creativity works.

The two views of design considered so far, Woodson's and Alger and Hays', are similar. A series of alternative designs are produced or conceived by some method; the most suitable is then chosen by some means; and the details of the design are worked out to produce the final solution. Christopher Alexander presents design in an entirely different light in his book, Notes on Synthesis of Form. He begins with the idea that design is an attempt to achieve fitness between two entities, the form and the context. The form is the solution to the problem. The context defines the problem. (12) In his own words, "the form is a part of the world over which we decide to shape while leaving the rest of the world as it is," and "the context is that part of the world which puts demands on this form." (13) Fitness is the relation of compatibility between the form and the context. Design, therefore, is the task of avoiding a number of specific conflicts between the form and its context.

The design problem, as formulated by Christopher Alexander, is not an optimization problem of satisfying one or a number of requirements in the best way. This, as he points out, exists because it is

important only to prevent conflicts between the form and the context.

Furthermore, the design problem, as formulated by Alexander, is not a selection problem. He contends that two things are necessary to solve a problem by selection. First, all the possible solutions must be expressed symbolically. Second, the criteria for solution must be represented in the same manner. Then the alternatives can be compared with the criteria to select best (14). For building design there is no method to generate new alternatives symbolically and no way to express the criteria for success. Therefore, he contends that building design is not a problem of selection.

These differing views of design bring up the question of what exactly constitutes the "Design Process." Is it a selection process; is it an optimization process; or is it a process to avoid certain conflicts between the "form" and the "context"? Is it a combination of these? If so, from what is the selection made; what is optimized; and what conflicts must be avoided?

CHAPTER III

PROCEDURE

The procedure is based on the theory that repeated application of problem solving followed by generalization is the typical method used to learn to solve problems. A fifth year architecture student* and a M.S. student in Civil Engineering** working together attempted to put this theory into practice in investigating the preliminary stage of building design. Two building design projects were undertaken. The students documented their efforts from receiving the problem to the production of the preliminary design. After each project, generalizations were made on the design process. This approach involves learning by doing and generalization based on the experience gained.

The first project, assigned during the winter quarter, was the design of a surburban Presbyterian Church. This project was approached by the two students strictly on their own with no help from the faculty advisers and with no reference to textbooks on design. Proposing a general design procedure, the students tested it in the specific design given. After the project was completed, each student prepared a report in which he evaluated the results of the project and set forth a new design process based on the experience gained.

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* William B. Hendrick

** C. Nelson Williams

The second project, assigned during the spring quarter, was the design of a parking garage in the Central Business District of a large city. The design process proposed after the completion of the first project was tested by trying to follow it in this project. At first, the students received no help as in the first project, but soon after the quarter started, they were allowed to use reference work on the design process. At this time, the writer began the library research on the design process and had weekly meetings with Professor Dinnat to discuss the current project and the design process in general. The documentation of this project as well as that of the first is given in the Appendix II and III and is the basis of this thesis.

CHAPTER IV

DISCUSSION OF RESULTS

This section will point out the highlights and items of significance found in the documentation of the two design projects. The two projects are summarized in the flow charts given in Figures 4 and 5. The detailed documentation is given in the Appendix.

Even though Project I was not fully completed and resulted in only an adequate solution, it points out the importance of time in the design procedure. The time available to concentrate on Project I was limited because the project was begun late in the winter quarter, both students were carrying a full course load, and the approach to the project was not understood. Since the time was limited, the students attempted only to satisfy the requirements and not to accomplish the goals. Because the purpose of the research was to investigate the preliminary design process and because the element of time limits the preliminary design process, the main part of this discussion will be based on Project II in which time was not such a significant factor.

One of the major problems encountered in studying the preliminary design was the definition and significance of terms used. In the beginning of design Project II, the "List of Attributes" of the parking facility was established. This list is given on page four of Appendix III and contains:

1. Provide at least five hundred parking spaces.
2. Permit the lowest parking rate to return to the owner 10% of

his invested capital annually.

3. Provide easiest entrance, circulation, and exit.

On reinvestigation of Project II, it was determined that the "List of Attributes" contained both requirements and goals. The first attribute is really a requirement since the parking facility must provide five hundred parking spaces to be satisfactory. The second attribute begins with a goal to "Permit the lowest parking rate." This is a goal because it is a desired characteristic of the building, but is not essential to the building. A parking facility which does not have the lowest parking rate may be a solution to the problem. The last part of the second attribute is a requirement since the solution must "return to the owner 10% of his invested capital annually," or it will not be built. The third attribute is another combination of a requirement and a goal. The requirement is to provide entrance, exit, and circulation paths for the vehicles. The goal is to provide the easiest entrance, exit, and circulation. It is essential for the parking facility to have an entrance, exit, and circulation path; but it is only desirable, not necessary, that it provide the easiest entrance, exit, and circulation. The difference between a requirement and a goal is very important, but at first they were combined under the term attribute.

The requirements of a building result from three sources, the function of the building, the constraints of the particular problem, and the means to accomplish a goal. This is shown in the Requirements established for design Project II, which are as follows:

1. Storage spaces for the vehicles.
2. Entrance and exit for the vehicles.

3. Means of transporting the vehicles between the entrance and exit and their spaces.

4. The facility must fit on the lot.

5. The facility must hold five hundred vehicles.

6. The facility must return to the owner 10% of his invested capital annually.

7. Stable structure strong enough to support the vehicles on multi-levels.

8. Entrance and exit for the customers.

9. Direct exit from each parking level to the street without circulating through another level.

10. Entrance on both major streets.

Requirements Nos. 1, 2, 3, 7, and 8 result from the function of the building. The basic function is the storage of vehicles. Because of this basic function, the facility must satisfy the first three Requirements. The functions that the building must perform increase as the design progresses. When the decision was made that the facility must be multi-level, the Requirement No. 7, that the structure must be stable and strong enough to support the vehicles on multi-levels, resulted. Furthermore, after the decision to have self parking was made, it became necessary to provide entrance and exit for the customers which is Requirement No. 8. Therefore, some of the requirements result from the functions of the facility which increases as the design progresses.

Requirements Nos. 4, 5, and 6 result from the constraints of the particular problem. A constraint is an element of the problem that is

not subject to change at any time. Since the size of the lot is a constraint, the building must fit on the lot. This is Requirement No. 4. The capacity of five hundred cars is another constraint of the problem and leads to Requirement No. 5. The amount of revenue returned to the owner annually is the constraint that establishes Requirement No. 6. The constraints of the problem are usually all known at the beginning; therefore, the requirements that result from them can be established early and do not depend on any design decision as do some of the requirements which result from the function of the building.

The other two Requirements, Nos. 9 and 10, result from a means to accomplish a goal which is a specific way to achieve a characteristic desired in the building. Ordinarily, this would not be a requirement. However, if the designer is convinced that no solution will result unless it contains a certain means to accomplish a goal, then the means becomes a requirement. This type of requirement is established purely subjectively on the opinion of the designer; whereas, the other requirements were determined objectively without involving the opinion of the designer.

All of the requirements have equal importance; if any one of them is not satisfied, then there is no solution. However, it is not possible to determine if some requirements are satisfied until the detail design stage. For example, it is not possible to know if the structure is stable and strong enough to support the vehicles on multi-levels, Requirement No. 7, until the members have been designed and analyzed. Furthermore, it is not possible to determine if the garage will return 10% of the invested capital to the owner annually, Requirement No. 6, until the structure has been designed and the cost estimated. These Requirements

were assumed satisfied by all alternatives in the design Project II. The details in the detail design stage are usually worked out to insure that this type of Requirement is satisfied.

Goals are characteristics desired in the building. Some goals are derived from the requirements. Other goals are derived from the special interest of several groups such as the public interest in general, the professional interest of the architects, and the professional interest of the engineers. This is shown in the Goals which were set for design Project II. They are as follows:

1. To eliminate a parking problem.

2. To provide the lowest parking rate per car.

3. To provide entrance and exit with the minimum amount of interference with the existing traffic.

4. To provide the most efficient circulation path between the storage spaces and the entrances and exits for the vehicles.

5. To be most appealing and convenient to the user.

6. To provide the most efficient circulation path between the storage spaces and the entrances and exits for the customers.

7. To provide the most flexible structural lay out.

The Goals Nos. 3, 4, and 6 are extensions of the Requirements. Goal No. 3 is an extension of Requirement No. 2. The Requirement is that an entrance and an exit must be provided for the vehicle. This leads to the Goal of providing the most efficient entrance and exit. Likewise, Goal No. 4 comes directly from Requirement No. 3. The Requirement is that a means of transporting the vehicles between the entrance and exit and their storage spaces exist. The Goal is to provide

the most efficient means of transporting the vehicles. Requirement No. 8 leads to Goal No. 6. Goals Nos. 1, 2, 5, and 7 are independent of the Requirements. The public interest is reflected in goals Nos. 1, 2, and 3. The professional interest of the architects is reflected in goals Nos. 4, 5, and 6. The professional interest of the engineers is reflected in goal No. 7.

Goals present two difficulties, the difficulty of determining the importance of accomplishing a certain goal and the difficulty of determining the degree of accomplishing a goal. Unlike the requirements, the goals do not have equal importance. In Project II, the relative importance of each Goal was not considered directly, but two Goals were given precedence over the others by making the means of accomplishing them a Requirement. The Requirement No. 9, to provide direct exit from each parking level to the street without circulating through another level, is a means to accomplish Goal No. 4, to provide the most efficient circulation pattern. Likewise, Requirement No. 10, to provide entrance on both major streets, is a means to accomplish Goal No. 5, which is to make the garage most appealing and convenient to the user. These two Goals were given precedence over the others based solely on the opinion of the designers.

This raises the question of whether it is essential to determine the relative importance of the goals and, if so, how? The relative importance of the goals must be determined in order to settle conflicts that arise between means to accomplish different Goals. This is illustrated in Project II. To accomplish Goal No. 3, which is to provide entrance and exit with the minimum amount of interference with the

existing traffic, the students considered it important to separate the entrance and the exit by using one major street for the entrance and one for the exit. However, to accomplish Goal No. 5, which is to be most appealing and convenient to the user, Professor Joseph N. Smith maintained that there should be entrances from both major streets. The means to accomplish these two Goals conflicted. Here, the method suggested by Professor Smith to accomplish Goal No. 5 was given priority, but in actual practice it is not so easy to determine the hierarchical arrangement of the goals.

Also, the degree to which a Goal is accomplished is determined subjectively. In design Project II, this was done by comparing how well each alternative accomplished the Goals. This is illustrated in the second concept decision in which it is decided to use a Ramp Type Garage instead of a Mechanical Parking Garage or an Underground Parking Garage. The decision is based on Goal No. 2. It was assumed that all three types could satisfy the Requirements, but the cost of building and operating the three alternatives would be different. It was concluded that the Ramp Type Garage would be the least expensive to build and operate for this particular problem so that it would best accomplish Goal No. 2, to provide the lowest parking rate. The degree of accomplishment was not determined absolutely, but only with respect to the alternatives considered. The rating of how well each alternative would accomplish the Goal is the opinion of the designers based on the information they had obtained about garages already built and operating.

Before the concept decisions are considered in detail, the types of decisions made in the preliminary design process will be examined. The first is to decide if enough Requirements have been established to

insure that the building will function properly. It is not necessary to decide if the list of requirements is exhaustive at first because all the requirements cannot be established in the beginning since some result from the functions of the building which increases as the design process progresses. For example, in the beginning of design Project II, only the first six Requirements were established. These were necessary to insure that the parking facility function properly and meet the constraints of the problem.

After the designer decides that enough requirements have been established, he proceeds to make the concept decisions by which the design concept is developed. Each concept decision is a series of three decisions which result in the choice to use one alternative bound as the bound on the solution instead of other alternatives. The first of the three decisions is the selection of alternative bounds. The second is the decision of whether enough alternatives are proposed. The third is the decision among the alternatives to determine the bound on the solution. The first two decisions depend on the judgement of the designer. The third decision involves two steps, each alternative is examined to determine if it can satisfy all the requirements, and how well each alternative accomplishes the goals is compared to how well every other one accomplishes them. The alternative that satisfies all the requirements and best accomplishes the goals is chosen as the solution. The concept decisions produce a series of bounds on the solution which are at first very wide, encompassing many possible design concepts, but as more concept decisions are made the bounds become increasingly narrow until the design concept is reached and the

preliminary design stage is complete. The significance of the three decisions, which make up each concept decision, and the progression of the concept decisions toward the design concept will be illustrated by examining the concept decisions made in Project II.

The first concept decision is given on page six in Appendix III. In the first of the three decisions, the designers decided to consider the most general parking facilities. In the second decision, the designers decided that a single level parking facility (parking lot) and a multi-level parking facility (parking garage) were the most general parking facilties. To make the third decision both alternatives were first compared to the Requirements. It was found as shown in the Appendix III that five hundred spaces could be provided in approximately four parking levels. Therefore, a single parking level could not be a solution because it violated Requirement Nos. 4 and 5. It was assumed that a multi-level parking facility could satisfy all the Requirements. Therefore, the first concept decision resulted in the conclusion that the parking facility must be a multi-level one. This decision was based on the assumption that a parking facility requires three hundred square feet per space. The three hundred square feet per space includes the storage space for each vehicle plus the proportion of the space used for circulation between the space and the entrance and exit. This was an average figure based on past solution. After this concept decision was made, Requirement No. 7 was added to the list of Requirements.

The second concept decision is given on pages seven to eleven in the Appendix III. In the first of the three decisions, the designers

decided to consider the types of multi-level parking facilities. In the second decision, they decided that Mechanical Parking Garages, Underground Parking Garages, and Ramp Type Garages were the exhaustive list of alternative for multi-level parking facilities. As explained previously, the third decision concluded that the solution must be the Ramp Type Garage because it satisfied all the Requirements and best accomplished Goal No. 2 since it would be the least expensive to build and operate. This decision was based on evaluation of examples of the three alternatives.

The third concept decision is given on pages twelve to twenty-four in Appendix III. The first decision was to consider the major variations in the Ramp Type Garage. The second decision was that there are two major variations, attendant parking and customer parking. To make the third decision both alternatives were compared to the Requirement. It was assumed that they both could satisfy all the Requirements. Next how well each alternative accomplished the Goals was compared. Based on the economic analysis which is given in the Appendix III, it was concluded that the customer parking garage would produce the lower parking rate; therefore, it would accomplish Goal No. 2 better than attendant parking. Furthermore, it was concluded that a customer parking garage would be more attractive to the customer, therefore, it would accomplish Goal No. 6 better than the attendant parking garage. The third concept decision concluded that the Ramp Garage should be customer parking. This decision was based partly on the economic analysis which used average figures obtained from past solutions, and partly on the opinion of several authorities as to which variety appealed most to the customer.

The fourth concept decision is given on pages 25 to 41 in Appendix III. In the first of the three decisions, the designer decided to consider the type of customer ramp garages. The second decision was that the types can be divided into straight ramp between full parking levels, helical ramp between full parking level, split levels, ramped floors, and a combination of these. Twelve alternatives were proposed as shown in the Appendix III. Since all twelve could satisfy the Requirements, the decision to use one alternative as a solution must be based on how well each alternative accomplished the Goals. Comparing the alternatives was difficult. The result was that how well each alternative accomplished the Goals was not compared, but the method of accomplishing the Goals in each was compared. The designers decided that the best method to accomplish Goals Nos. 3, 4, and 5 was to have one way traffic in the aisles, to have the entrance and exit on different streets, and to provide direct exit to the street from any floor without re-circulating through the garage. This was a purely subjective decision based on the study of past ramp garages. Furthermore, the designer was convinced that no solution would result unless it contained a direct exit from each parking level to the street without re-circulating through another level. Therefore, this method of accomplishing a Goal became a Requirement because of the prejudice of the designer. This Requirement eliminated ten of the twelve alternatives, leaving only alternative Nos. 11 and 12 to be compared. After talking with a parking consultant, alternative No. 12 was chosen because it accomplished Goal No. 4, to provide the most efficient circulation pattern, better than alternative No. 11 in the opinion of the consultant. The decision to use alternative

No. 12, which used an inclined ramp with a helical exit ramp, was based on the prejudice of the designer and the opinion of a parking consultant. This decision was avoided since the designers were unable to compare how well each alternative accomplished the Goals, but an alternative was chosen subjectively.

This alternative was shown to Mr. Smith, one of the faculty advisors, who brought out several points explained in the Appendix III. The major point was that there should be an entrance on both major streets to accomplish Goal No. 5, to be most appealing and convenient to the user. This is a means of accomplishing a Goal, but it became Requirement No. 10 because the designers were convinced it was necessary for a solution.

The fifth concept decision is given on pages forty-two to forty-eight in Appendix III. In the first of the three decisions, the designers decided to consider combinations of inclined ramp garages with a helical exit ramp. The second decision resulted in the conclusion that the five alternatives shown were the only combinations that would meet all the Requirements. The alternative shown on page forty-eight was chosen as the solution because it accomplished Goals Nos. 3, 4, and 5 better than any other alternative. Since this was the last concept decision, the solution is the design concept.

A very important part of design is the obtaining of and use of information. Information is used to establish the Requirements and to set the Goals. Also, it is used in making all the decisions. In Project II, past solutions were studied to determine the necessary elements and to set the desirable characteristics. This study was contained until enough information had been obtained to assure the designers that they had established the Requirements necessary to insure that the

parking facility functioned properly. After this was determined, the designers proceeded to the concept decision. In the concept decision, enough information was necessary to insure that the list of alternatives was extensive. Also, information was necessary to compare the alternatives to the Requirements and to evaluate how well each alternative accomplished the Goals. This information was obtained from the study of past solutions and the opinions of authorities.

In this paper information is considered to consist of unorganized or unrelated facts and authoritative opinions derived from reading, observation, or instruction. The facts are undisputable. An example of some of the facts used in Project II is the length and width of a car stall whose minimum size is eight feet by eighteen feet. This size allows space for the car and space for a person to enter and exit from the car. The space needed is set by the physical dimensions of the car and are undisputable. On the other hand, the authoritative opinions may vary and may even be conflicting. The students interpreted that the author of Traffic Design of Parking Garages recommended that a direct exit to the street from each parking level should always be provided to accomplish Goal No. 4, which is to provide the best circulation. Mr. Smith maintained that this was not important in a garage of less than five to seven levels. The opinions of the two authorities, the author and the faculty advisor, conflicted in this case. Here, the author's opinion was given priority.

Another important point brought out in this research is the position of Civil Engineering Structural Theory in the preliminary design stage. The Theory of Structures plays an important part in

deciding among the alternatives and establishing the design concept if the structural form has not already been well established. But if the structural form is well established, then the theory of Structures will only be important in the detail design stage. This is illustrated by comparing the two design projects. In Project I, the first alternative was determined by the architectural student. He proposed an entire design concept at once by setting the form, the plan, the structure, and the material. As explained in Appendix II, this resulted in a structure that was not practical to build. The large channel shaped, concrete members would be extremely heavy and would result in an excessive foundation for the size of the building. Moreover, there would be a very difficult problem connecting the massive side elements to the slender roof elements in order to obtain strength and stability. Because of the structural Requirement of providing a stable structure, this alternative was rejected and another one based on structural considerations was proposed. Therefore, in a design project in which the structural form has not been well established, such as the church in Project I, the Theory of Structures plays a very important part in deciding among the alternatives and establishing the design concept. In Project II, however, the Theory of Structures did not play an important part in deciding among the alternatives or in establishing the design concept. This is because the structural form for the parking garages considered had already been well established.

CHAPTER V

CONCLUSIONS

1. The terms used to describe the design process must be precisely defined in order to understand the process.

2. For every building, there exists a set of Requirements which must be satisfied.

3. The Requirements of a building result from three sources:

A. The function of the building.

B. The constraints of the particular problem.

C. The method to accomplish a Goal. These Requirements are established subjectively.

4. It is not possible to determine if some Requirements are satisfied until the detail design stage. The amount of time required to check them limits their usefulness in the preliminary design stage.

5. An optimum solution depends upon the accomplishment of the Goals. But what constitutes the accomplishment of a Goal is subject to interpretation.

6. A method to accomplish a Goal becomes a Requirement when there is only a single method to accomplish it.

7. In the preliminary design stage, the Goals present two difficulties, the difficulty of determining the importance of accomplishing a certain Goal and the difficulty of determining the degree of accomplishing a Goal.

8. The Goals in which the methods to accomplish them can be readily compared play a more important part in the preliminary design

stage than the Goals in which the methods to accomplish them can not be readily compared.

9. The necessary decisions in the preliminary design stage are:

A. The first decision is to decide if enough Requirements have been established to insure that building will function within the constraints of the problem.

B. Next a number of Concept Decisions are made. The Concept Decisions produce a series of bounds on the solution which are at first very wide, encompassing many possible design concepts, but as more decisons are made the bounds become increasingly narrow until the design concept is reached and the preliminary design stage is complete. Each Concept Decision is a series of three decisions:

(1) The selection of alternative solutions.

(2) The determination of whether enough alternatives are proposed.

(3) The decision among the alternatives to determine a bound on the solution. This involves two steps.

a. Each alternative is examined to determine if it is satisfied by all the Requirements.

b. How well each alternative accomplishes the Goals is compared to how well every other one accomplishes them.

10. Only if the structural form has not already been well established, will the Theory of Structures play an important part in deciding among alternatives and establishing the design concept.

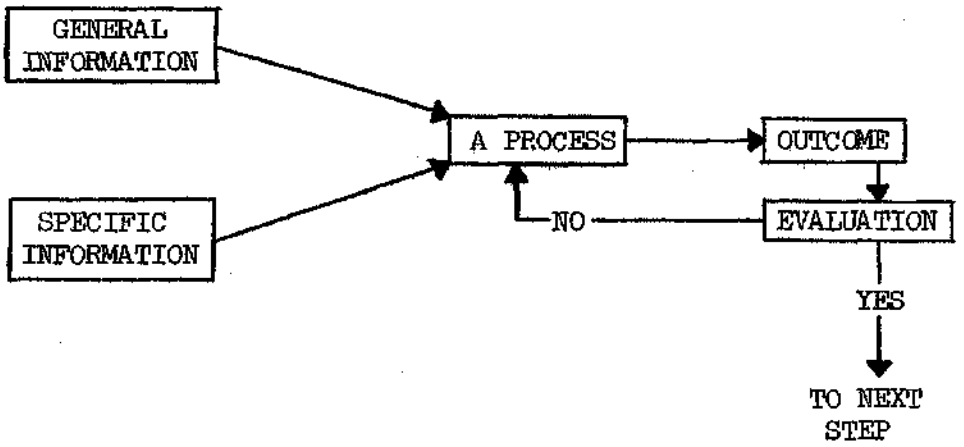


Figure 1. Design Process According to Woodson

1. Recognizing
2. Specifying
3. Proposing Solution
4. Evaluating Alternative
5. Deciding on a Solution
6. Implementing

Figure 2. Design Process According to Alger and Hays

	Specification #1	Specification #2	Specification #3	...
Alternative #1				
Alternative #2				
Alternative #3				
.				
.				
.				
.				

Figure 3. Decision Table

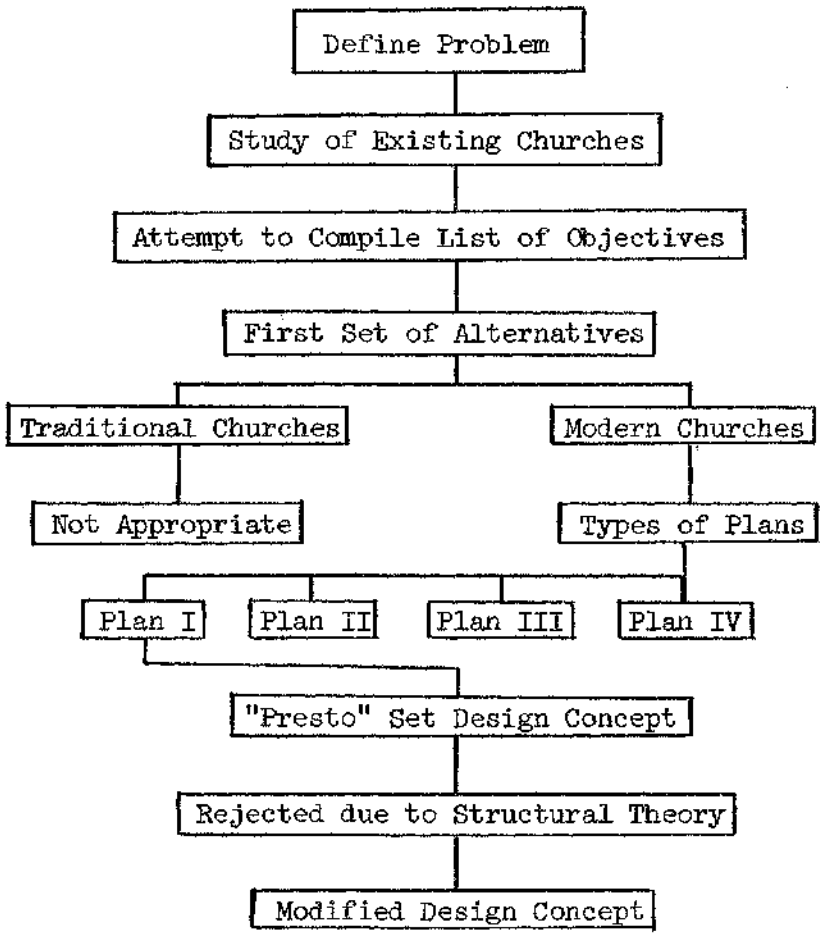
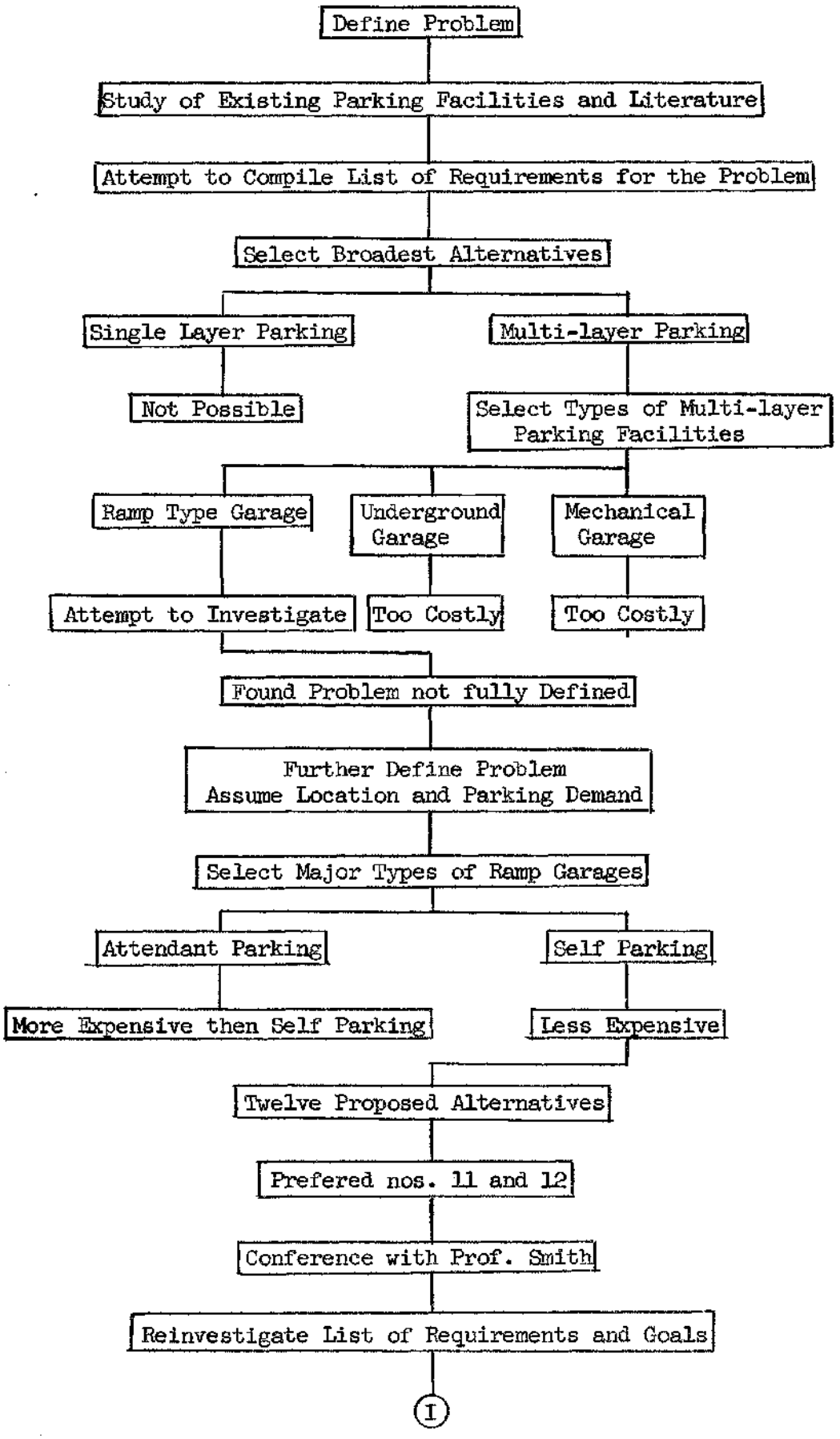


Figure 4. Flow Diagram of Project I - Surburban Church


Define Problem
Study of Existing Parking Facilities and Literature
Attempt to Compile List of Requirements for the Problem
Select Broadest Alternatives
Single Layer Parking
Multi-layer Parking
Not Possible
Select Types of Multi-layer Parking Facilities
Ramp Type Garage
Underground Garage
Mechanical Garage
Attempt to Investigate
Too Costly
Too Costly
Found Problem not fully Defined
Further Define Problem
Assume Location and Parking Demand
Select Major Types of Ramp Garages
Attendant Parking
Self Parking
More Expensive then Self Parking
Less Expensive
Twelve Proposed Alternatives
Prefered nos. 11 and 12
Conference with Prof. Smith
Reinvestigate List of Requirements and Goals
I

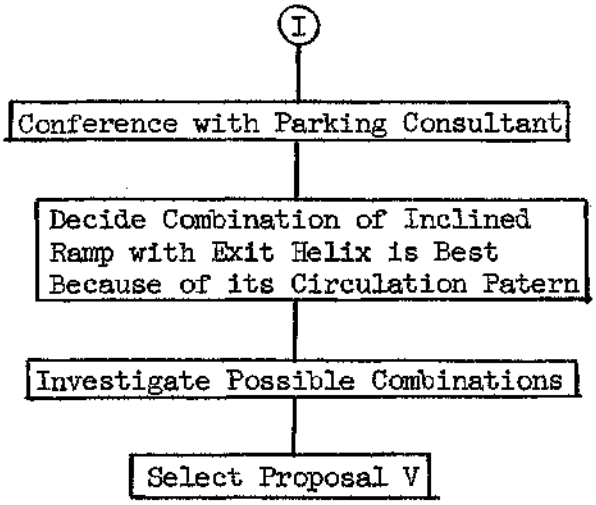


Figure 5. Flow of Project II - Parking Garage

APPENDIX I

GLOSSARY

1. ALTERNATIVE BOUNDS represent possible bounds on a solution.

2. BOUND ON A SOLUTION is the limits imposed on the design concept of a building as a result of a concept decision.

3. BUILDING DESIGN PROBLEM is the statement proposing the building to be designed.

4. BUILDING DESIGN PROJECT or DESIGN PROJECT is the entire understanding of designing a building. It includes the statement of the problem, the steps to solve it, and the solution.

5. CONCEPT is a pictorial representation of a building which lacks the details to be constructed.

6. CONCEPT DECISION is a series of decisions which result in the choice to use one alternative bound on the solution instead of others. The concept decision involves selecting the alternative bounds, deciding if an exhaustive number of alternatives are considered, and finally deciding on the bound on the solution to use.

7. CONSTRAINT (BOUNDARY CONDITION) is a physical element that is not subject to change at any time.

8. DECISION is a conclusion arrived at after consideration.

9. DESIGN CONCEPT is the solution which is the output of the preliminary design stage.

10. DESIGN DECISION is a decision made in a building design project.

11. DESIGN OF A BUILDING is the task of producing the plans from which a building can be constructed.

12. DETAIL DESIGN STAGE is the division of the design of a building in which the details necessary to make the concept constructable are worked out.

13. GOAL OR OBJECTIVE is a characteristic desired in the building. These are striven for in the building, but they are not indispensable. They can be accomplished to a varying degree.

14. INFORMATION is unorganized or unrelated facts or authoritative opinions derived from reading, observation, or instruction.

15. MEANS TO ACCOMPLISH A GOAL is a specific way to achieve a characteristic desired in a building.

16. OBJECTIVE means exhibiting or characterized by emphasis upon or the tendency to view events, information, ideas, etc. as external and apart from self consciousness. It is usually used to modify a decision which is detached, impersonal, and unprejudiced.

17. PARAMETER is a physical element of a building that may assume different schemes during design only, but is constant after construction.

18. PARKING FACILITY is any general place where cars can be stored.

19. PARKING GARAGE is any structure built for the purpose of storing cars.

20. PRELIMINARY DESIGN PROCESS is the method by which the design concept is established.

21. PRELIMINARY DESIGN STAGE is the division of the design of a building in which the design concept of the building is originated.

22. REQUIREMENT is a necessary specification for the building. It is essential to the building and is either satisfied or not.

23. SOLUTION is a plan which describes a building that satisfies all the requirements and accomplishes any number of the goals to any degree.

24. SUBJECTIVE means exhibiting or affected by personal bias, or background. It is usually used to modify a decision which is based on the personal interpretation of information.

25. VARIABLE is a physical element that may assume different schemes at any time, either during design or after construction.

APPENDIX II

A SUBURBAN CHURCH

Appendix II contains a statement of the first design problem and the complementary information which was provided, the proposed design process, the documentation of the design, and summary and analysis of the process.

A SUBURBAN RELIGIOUS FACILITY

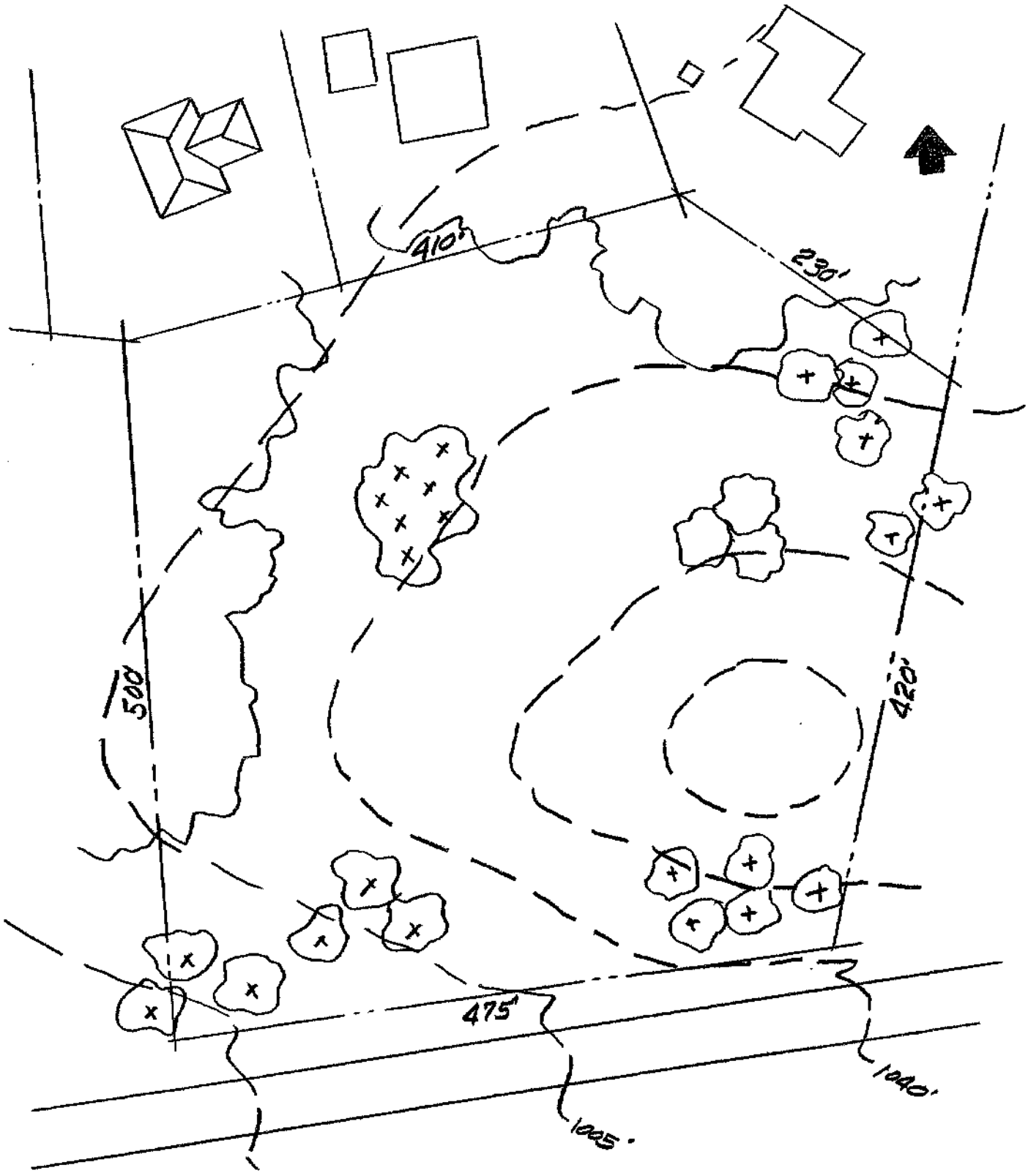
It is required to design a facility for a religion of your own choosing. The church or temple shall seat 400 persons. Provide for the appropriate liturgical and musical program. Above all, the building shall be an architectural space that expresses the basic beliefs of the particular group.

The entire building shall have full climate control.

The site is located in Sandy Springs, Georgia.

Space Requirements:

1.	Church or temple seating 400 persons.		
2.	Choir practice and robing rooms		3,000 sq. ft.
3.	Pastor's study and toilet		250 sq. ft.
4.	Secretarial and waiting space		250 sq. ft.
5.	Work room for "lay groups"		200 sq. ft.
6.	Instructional space	(approx.) --	5,000 sq. ft.
7.	Toilets		
8.	Vestry and sacristies if required		
9.	Nursery		
10.	Parking for 100 cars.		
11.	Future social hall (show on site plan only)		6,000 sq. ft.



Site Plan

The BELIEF of the Presbyterian:

GOD is a spirit, infinite, eternal, and unchangeable; all-powerful, holy, wise, good, true and just, hating all sin. He is merciful and gracious, not willing that any should perish. He exists in three persons; the Father, the Son, and the Holy Spirit, who are one God, the same in substance, equal in power and glory. "God is love."

SALVATION is freely offered to all men by God who, rich in Mercy, sent Christ as the saviour. This salvation becomes efficacious only in those who believe in Jesus Christ unto eternal life.

CHRIST is the eternal son of God. He became truly man, conceived by the Holy Ghost, born of the Virgin Mary, yet without sin. He is both God and man, and the only perfect mediator between God and man. By a life of perfect obedience, and by His sacrificial death, He satisfied divine justice, atoned for man's sins, and reconciled man to God. He rose from the dead, makes continual intercession for us, and will come again to receive and reward us, and to judge the world.

The BIBLE is God's Word, His will for man, and man's duty to God. It is the only infallible and authoritative rule of faith and life.

The PURPOSE of God includes all events, but does not deprive man of freedom, nor make God the author of sin.

CREATION was for the manifestation of God's glory. Man was made with a freedom of his own will.

SIN is the violation of God's law, and all men, by relationship to Adam, are born with a sinful nature, from which all actual transgressions procede, and out of which condition no man can deliver himself.

The HOLY SPIRIT applies the redemption purchased by Christ. He

persuades and enables men to obey the call of the gospel, and dwells continually in the believer as the spirit of truth, holiness, power and comfort, and is thereby the author of all Chirstian experience.

The CHRISTIAN LIFE is that of the Christian, the child of God, full of good works that are not the ground of salvation, but the fruits. Believers may fall back, but God does not abandon them, but forgives, chastens, and restores.

The CHURCH universal is acknowledged, including all ages. Chirst is the head. The church invisible consists of all the redeemed. The church visible is composed of all those who profess faith in Christ, and their children. It is the duty of all believers to openly confess their faith and to unite with the church. The mission of the church is spiritual, its work being to witness the truth of God to the ends of the earth. The church is separated from the state. The form of government of a church is not essential to its existence. The sole condition for membership in the church is a credible confession of Christ as Saviour.

SACRAMENTS consist of Baptism, symbolizing the work of the Holy Spirit, and the Lord's Supper, symbolizing the sacrificial death of Christ. Sprinkling or pouring is the scriptural mode, but the mode is not essential to the validity of the sacrament. Children of believers are baptized on the faith of their parents, but the parents enter into formal covenant with God in the sacramental act.

The SOULS of believers are at their death made perfect in holiness, and immediately pass into glory. The day of judgement comes at the resurrection.

Heaven and Hell are the only two final states of existence. There is no purgatory or probation. Man retains his identity after

death, and there will be recognition in the future life.

The GOVERNMENT of the Presbyterian Church in the United States:

The first modern Presbyterian Book of Order was written by John Calvin in 1542. John Knox, who had been with Calvin for several years, returned to Scotland and wrote the first "Book of Discipline" for the Presbyterian Church of Scotland, in 1560.

In 1643, a body called the Westminster Assembly met in London, and wrote the Confession of Faith, the Catechisms, and "The Form of Presbyterian Church Government." These were adopted by the Presbyterian churches of England, Scotland and Ireland.

This Westminster "Form of Church Government" became the basis of church law in the American Presbyterian Church. It was practically re-written in 1788, in preparation for the first General Assembly, held in 1789.

On December 4, 1861, the Southern Presbyterians withdrew from the Church, U.S.A., and organized the General Assembly of the Presbyterian Church in the United States. It adopted the Form of Government and Discipline of the church that had been used since 1788, but, beginning in 1863, revisions and amendments became numerous until 1921, when a thoroughgoing revision was proposed and adopted in 1925, which is the main content of the present "Book of Church order."

The church government is divided into five headings;

1. The Church, established by Christ for the edification and government of his people, the propagation of the faith, and the evangelisation of the world. It is His visible Kingdom of grace, is one and the same in all ages, and is for the gathering and perfecting of the saints.

2. The Members, all persons who make profession of their faith in Christ, and submission to his laws, and their children.

3. The Officers, who administer all its (the churches) powers, and are; teaching elders (ministers), ruling elders, and deacons.

4. The Courts, which practise ecclesiastical jurisdiction, jointly, over one or many churches.

5. The Ordination of officers is usually done by a court.

This doctrine of government is necessary to the order of the visible church, but is not essential to its existence.

The Head of the church is Christ, given all power by God, the church being His body. Christ has given doctrine, government, discipline and worship to his church. Christ is present with the church by His word and spirit. The church consists of all professors of faith and their children, and all denominations which maintain the word and sacraments in their fundamental integrity. The particular church consists of a number of worshipers professing Christian faith and their offspring associated together for divine worship and Godly living.

The Ordinaces of the church are: prayer, singing, and reading, expounding, and preaching the word of God. Administering the sacraments of baptism and the Lord's supper, fasting, thanksgiving, catechising, Christian education, offerings for the relief of the poor, extension of the gospel, exercising discipline, and other Christian causes.

The Organization of a church can be had only by the authority of the presbytery.

The jurisdiction of the church is in the hands of the session (ruling elders and pastor).

The Deacon's work is the collection and administration of offerings

for relief of those in need and the maintenance and development of the church work, under the supervision of the session. Their office is one of sympathy and service, after the example of Jesus. Their duty is to minister to the needy, sick, friendless and distressed, and to administer the offering, distribution, and the care of the property of the church. They are organized as a board, with the pastor as advisor. A deacon may serve on a committee. They are chosen by the people.

The Ruling Elders are officers for government. They possess the same authority as the teaching elders, or ministers, as well as the same eligibility to office in the courts. They are elected by the people.

The Courts are:

1. The session - maintains the spiritual government of a church.

2. The Presbytery - made up of the pastor and one ruling elder from each church in a district.

3. The Synod - made up of the minister and one ruling elder from each church in a district comprising at least three Presbyteries.

4. The General Assembly - the highest court, it represents all the churches in one body. It constitutes the bond of unity and peace among all its congregations and courts.

For each court, there is a moderator and a clerk.

The jurisdiction of the courts is moral and spiritual, ministerial and declarative. It has three areas of authority:

1. It may make no laws binding to the conscious, but may frame symbols of faith, bear testimony against error in doctrine or immorality in practice, both within and without the pale of the church. The court may decide cases of conscience.

2. The courts may establish rules for the government of the church.

3. Authority to refuse office, right to sacrament, or membership in a congregation.

A Comittee has as its purpose examining and reporting.

A Commission concludes and acts.

Vocation to office is by the calling of God through the Spirit. The government of the church is representative.

Ordination is by a court.

A Candidate for the ministry must present the evidence of a four--year degree and a full training in an approved seminary. He must be called to a congregation by election, and is ordained by the Presbytery.

The DISCIPLINE of the church:

Discipline is the exercise of authority given the church by Christ to instruct and guide its members, and to promote its purity and welfare.

The church is as a Mother, who protects her children for their own good.

An Offense is an act contrary to the Word and to the accepted writings such as catechisms, formularies of government, etc.

The Censures in the authority of the courts are:

1. Admonitions - formal reproof.

2. Suspension - temporary exclusion from the sacraments.

3. Excommunication - excision from the communion of the church.

4. Deposition - degradation of an officer from office.

Ministers may be suspended or deposed.

The WORSHIP in the church:

The Lord's day is to be remembered, and all worldly things put

aside.

To be included in the worship:

The reading of the scriptures.

Singing of psalms and hymns.

Prayer.

Preaching.

Offerings.

The children are under the care of the church.

The Communion time is determined by the session. The minister explains it and invites all members of any evangelical church to partake.

The minister is served before the people, and the elders after, by him.

Hendrick
1/19/67

THE DESIGN PROCEDURE

1. Full understanding of the program, its purpose and its scope.

2. The evolvement of the concept.

   a. Envisioning the building (s) as an element in its overall spatial environment.

   b. Envisioning the individual spaces of the building (s) as a part of the integrated whole.

3. General space studies of relationships of elements, etc. these are done at half the required scale of the final drawings and usually in the form of sketches.

4. More detailed studies of plans, elevations, sections, at the same scale as #3 above. Here a scale model is often helpful in working out important refinements of the design.

5. Preparation of the final drawings and other presentation requirements, working drawings, etc., at the required scale.

6. Final analysis of the design in terms of the original objectives. This step would best come before the preparation of the final drawings, so as to permit any necessary changes in the design.

The steps in the design procedure listed here have been purposefully architecturally, rather than structurally oriented. The reasons are twofold. First, it is believed that the intended research will be more valuable if, at the onset, the architecture student approaches the problem from the design phase, and the C. E. student approaches it from the structural phase. This is not to say however, that structural decisions are not a part of the design procedure for the architect. This brings out the second reason for architecturally orienting the above

list. The decisions made in designing a building do not concern themselves merely with esthetics and function. They also concern structural and mechanical problems which are inherent in design. The execution of the design procedure will, I believe, bear out the importance of the involvement of the architect in the structural and mechanical phases of the project, as well as the esthetic and functional relationships.

Nelson Williams
1/19/67

GENERAL PROCEDURE FOR BUILDING DESIGN

1. Define list of attributes of the building.
    a. Purpose of building.
    b. Space required to accomplish the purpose.
    c. Relations to its surroundings.
    d. Special requirements.
2. Preliminary Investigation.
    a. Location.
        (1) Area available.
        (2) Soil and subsurface condition.
    b. Weather conditions.
    c. Building code requirements--zoning laws.
3. Select possible designs based on list of attributes and preliminary investigation.
4. Investigate details of preliminary designs.
    a. Space requirement and space arrangement.
    b. Special structural requirements.
    c. Electrical and mechanical requirements.

d. Plumbing requirement.

e. Heating requirement.

f. Esthetic requirements.

5. Select most suitable design.

a. Economic.

b. Meeting requirement.

c. Esthetic.

6. Final design.

a. Detailed lay out.

Friday, January 20

MEETING HELD FOR PURPOSE OF COMPARING GENERAL DESIGN PROCEDURES

1. Great degree of similarity between the two procedures, except for wording.

a. Both procedures work from the general to the specific (i.e. begin w/ definition and understanding of program and work to more specific considerations concerning building type).

b. Williams' program gave more consideration to structural or loading conditions (i.e. weather, orientation, sun, snowload, wind conditions, etc.; electrical, mechanical, plumbing, etc.). Specific mention is made of esthetic requirements.

c. Hendrick's program does not mention structural conditions such as these, but assumes they would be considered in the design concept. No mention is made of esthetic requirements, as this is one of the ultimate goals of the designer and esthetic considerations are given inherently throughout the design process.

2. Objectives at the outset seem to be the same (as in step #1).

a. It was agreed that for the next meeting we would prepare a specific design procedure for the program issued. At this point we will proceed with the actual design of the building, after having further agreed upon our objectives.

Hendrick

SPECIFIC DESIGN PROCEDURE

1. Investigation of potentialities of site (i.e. Possible use of knoll as design element.

   a. Study of general location of facilities required.

   b. Study of general location of parking.

   c. Study of conveniences of parking to street and to building access.

   d. Study of religious symbolism as related to this program.

2. Evolvement of concept of design.

   a. Sanctuary is main element in building composition, therefore, it should dominate.

   b. Educational facilities are second in importance, both in size and function, so they might serve as secondary element to balance the sanctuary in composition.

   c. Study location of adjunct facilities (choir practicing rooms, offices, etc.) in relation to the two main elements.

   d. Consideration of structural system - how its use could possibly be integrated into the symbolism of the church.

   e. Major consideration must be given to the proposed addition, as the design must be a complete entity both before and after the inclusion of this element.

3. Study layout of church and adjunct facilities. More detailed plans involving room layout, space and function relationship, etc. Studies involving type of mechanical systems to be used, and their location relative to various rooms.

4. Section and elevation studies.

5. Possible mass model study to work out element massing and compositional balance, expression of structural system, etc.

6. Working out details. This is an extremely important step, as

the details contribute much to the success of a design.

7. Preparation of final presentation requirements. Here several different design concepts might be considered, and the most effective or best one would be selected and developed.

Nelson Williams
1/23/67

DESIGN PROCEDURE FOR SUBURBAN RELIGIOUS FACILITY

1. Define "objectives" or requirements of the program.
2. Preliminary designs.
    a. Space requirements.
    b. Location on site.
    c. Type of material.
    d. Types of framing systems possible.
3. Select possible design.
4. Investigate details of preliminary design.
    a. Architectural.
        (1) Space use.
        (2) Preliminary lay out.
    b. Structural.
        (1) Framing systems.
        (2) Framing lay out.
5. Select the most suitable design.
    a. Architectural.
        (1) Space Utilization.
        (2) Esthetic consideration.
    b. Structural adequacy.

c. Structural compatibility.

d. Structural economy.

6. Final design.

Janurary 23, 1967

MEETING HELD FOR PURPOSE OF COMPARING SPECIFIC DESIGN PROCEDURES

1. We noted here, as, in the general design procedures a considerable degree of similarity.

2. Hendrick's specific design procedure indicates that he has already given thought to certain design decisions. This can be a dangerous practice, as it can easily lead to preconceived ideas which are usually a detriment to a design solution because they often are not totally appropriate to the best solution. If the designer insists on incorporating the ideas because of some "pet" preference and sacrifices good design or economy for the sake of including these "pet" ideas, naturally the first solution will achieve less than total success.

3. Hendrick's procedure seemed to give some indication of design objectives (i.e. "sanctuary is main element in building composition, therefore it should dominate").

4. It was agreed that the next item on the agenda was to prepare program objectives. We discussed whether to prepare the objectives together or separately. It was decided that we would each prepare a list of objectives, in order to incorporate the maximum number of individual ideas in the design, and we were afraid we might eliminate some valid objectives if we discussed them prematurely.

Nelson Williams
1/24/67

OBJECTIVES FOR SUBURBAN RELIGIOUS FACILITY

1. The building shall express the basic belief of the Presbyterian Religion.

2. The building shall provide space for:

   a. The sanctuary as the main function.

   b. Instructional space is second largest space.

   c. Choir practice and robing rooms.

   d. Pastor's study and toilet.

   e. Secretarial and waiting space.

   f. Work rooms for lay groups.

   g. Toilets and nursery.

3. Parking for 100 cars must be provided within reasonal distance and ease of access to church and highway.

4. Space must be provided for future Social Hall. The building must be suitable both before and after additions.

5. Make use of site.

6. The church should be compatible with existing structures and surroundings.

7. Structural adequacy.

8. Structural economy.

   a. In lay out.

   b. In fabrication.

   c. In erection.

9. Structural compatibility.

Hendrick
1/24/67

OBJECTIVES OF THE PROGRAM

1. Esthetic:

   a. Relate building complex to site and surroundings.

   b. Create balanced composition W/sanctuary dominating (each element in the design should properly express its location and function). The hierarchy of form should not be only related to building elements, but should also be related to relative importance of function considered.

   c. Major consideration should be given to the program, to insure its integration with existing forms, as well as its functional relationship to other elements.

   d. Expression of structure in building forms.

2. Functional:

   a. Relate space elements to each other so that they permit good circulation.

   b. Achieve structural system that is practical, but does not limit esthetic considerations of building forms. (i.e. sanctuary vs. classrooms).

   c. Provide mechanical system which is compatible with needs of building.

3. Symbolic:

   a. Christ is the single most influential element in the Presbytery; therefore, the sanctuary must reflect the aim of the Presbytery to interpret his word and administer his teachings.

   b. The entire building complex must be designed so that it invokes reverance and respect, but not fear. The place of worship should be ethereal, but not depressing, as so many of our churches are. It should be inviting, but for reasons of wanting to learn and worship, rather than satisfying one's curiosity.

January 24, 1967

MEETING HELD FOR PURPOSE OF COMPARING LIST OF OBJECTIVE

1. Williams' list of objectives were more analytical than Hendrick's.

2. Williams' list of objectives included items listed in the program, and was similar in some respects to Hendrick's specific design procedure.

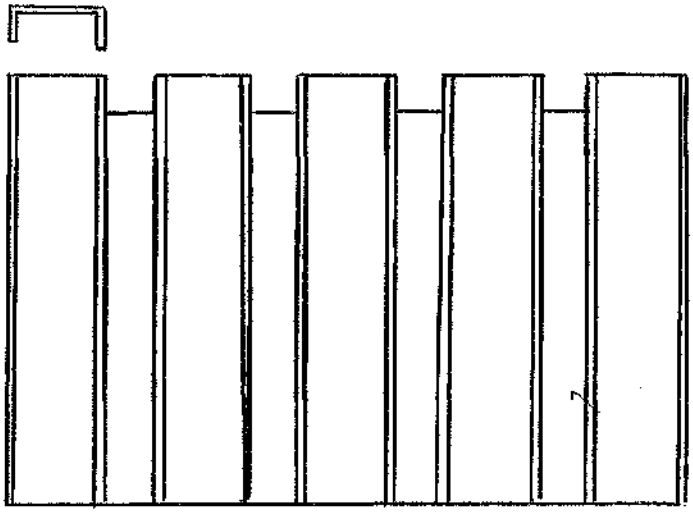
Nelson Williams
2/21/67

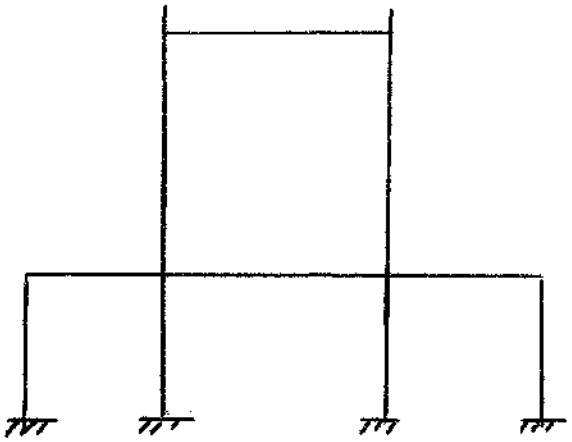
FIRST SOLUTION

At the beginning, the architectural student tried to impose too many restraints on the building form, plan, material, and structure. This resulted in a structure that was not practical.

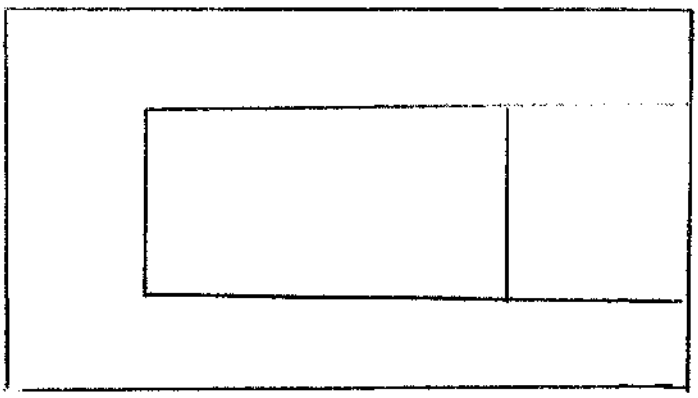
The large channel shaped, precasted concrete members would be very heavy. The weight would cause foundation problems possibly. Also obtaining stability by a continuous system of precast and poured in place concrete would cause erection problems. Any method of obtaining stability would be difficult with these large blocks.

The engineer recommended using steel or concrete rigid frame and building the channel shaped members as a curtain wall of some type.





Elevation



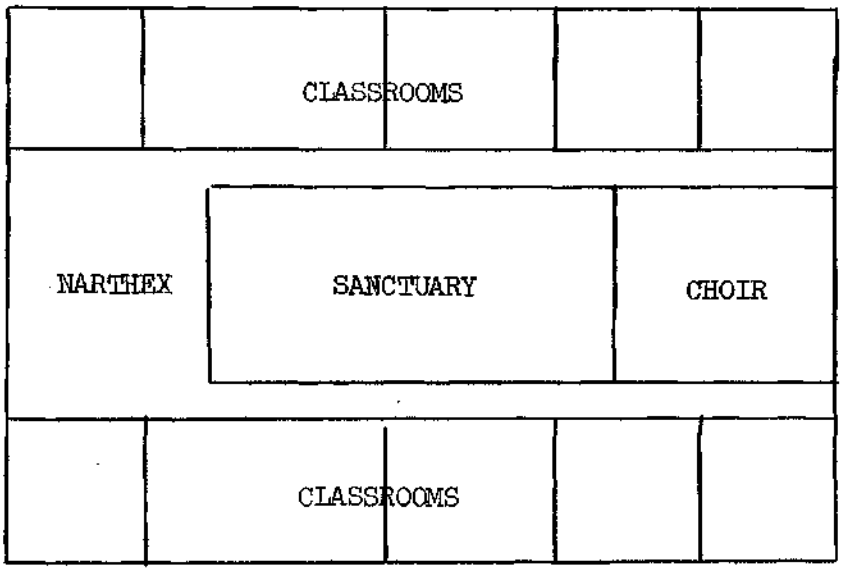
Plan

A PRESBYTERIAN CHURCH

The Presbyterian Church has no spire; does not make use of stained glass in the usual symbolic idiom; attempts to have the choir be a part of the congregation; does not make use of the altar (instead use communion table); and in general tries to integrate the congregation with the minister and other liturgical elements of the service.

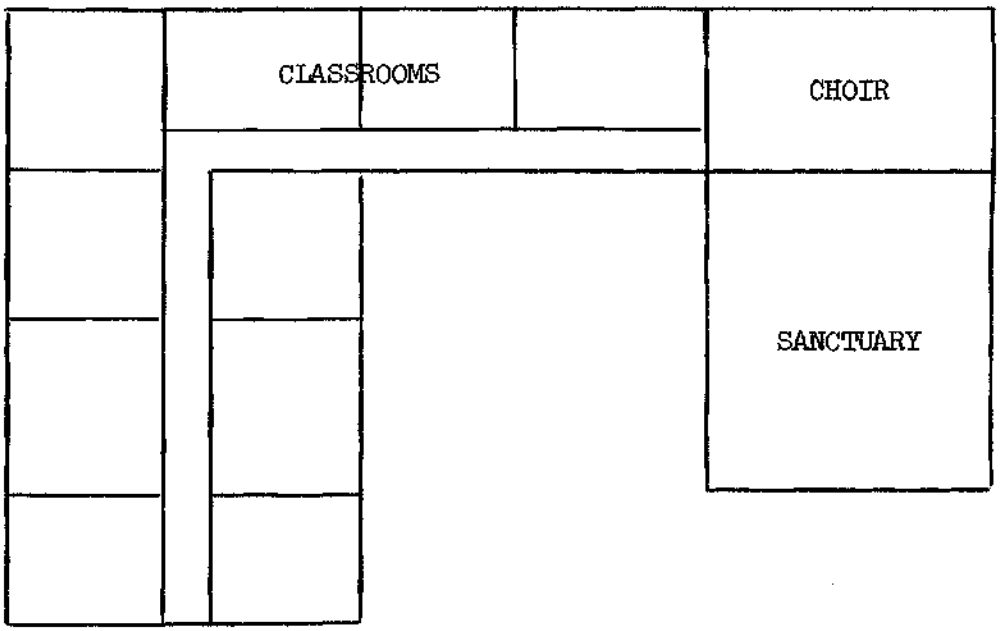
Part I:

An attempt to treat the entire groups of space as one building, with the nave as the dominating space.



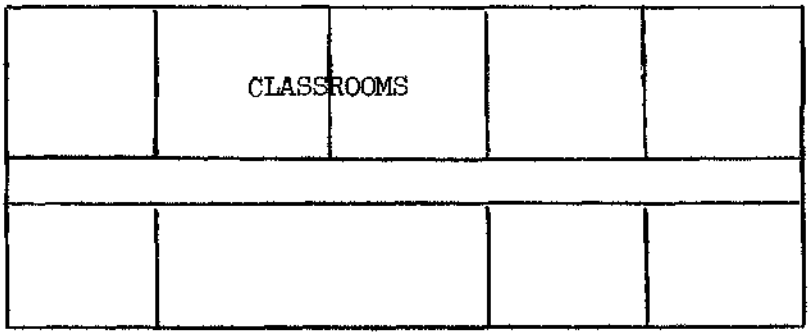
Part II:

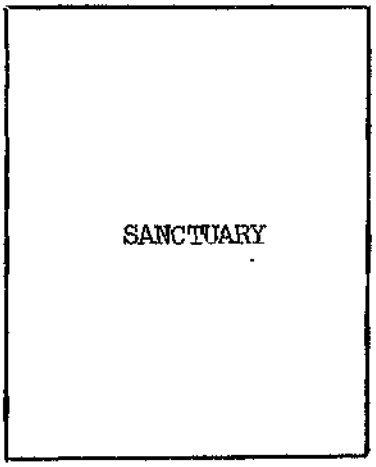
Divorcing the nave from the other spaces, and treating it as the dominating element with the adjunct spaces surrounding it. Possibly utilizing a courtyard.



Part III:

Completely removing the nave, treating is as a separate building. The other spaces would be treated in several different ways.





February 24, 1967

MEETING HELD FOR PURPOSE OF DISCUSSING AND CHOOSING A PLAN

1. It should be brought out here that a plan does not provide more than a skeletal space arrangement, or schematic space diagram. Many architects believe that there are just as many plans as there are building designs. Quite the contrary however, nearly every example of a building type can be classified as having been developed from a certain plan. For example, nearly every church scheme can be traced back to one of the plans sketched previously. It is important that the selection of the plan be appropriate to the program, as this constitutes partial success of the program. Certainly, however, the degree to which the designer develops the program is the major contributing factor to a design solution.

2. After discussing the various plans available, it was decided that we would use Plan III as a basis for our design. It seems that this plan would enable developing the church design in a scale recalling the suburban residential comunity in which it is to be built. Also, by separating the classrooms from the sanctuary, it was thought that a better circulation diagram would be arrived at.

Comment

I do not think we should have eliminated the other plans so soon without considering the effect of the combination of parti, form, structure, and material. The full possibilities of each plan can not be seen unless all the alternatives are considered. 3/31/67 C.N.W.

March 30, 1967
C. Nelson Williams

SUMMARY AND EVALUATION OF DESIGN #I, A SUBURBAN RELIGIOUS FACILITY

This paper will attempt to define the purpose of documenting the decisions made in the building design process, to explain the design process as formulated in Design #I, and to evaluate the outcome of carrying out this design.

The purpose of documenting the decisions made in the building design process is to define the "Design Process," and to enumerate the problems involved in the design of a building. This approach involves learning by doing, and then generalizing on the experience gained in problem solving. The repeated application of problem solving and generalizing is the typical method used to learn to solve problems. This process was followed in Design #I. First, a "Design Process" was proposed. Then a specific design problem was attempted and all decisions were recorded with accompanying reasons. Now the outcome is analyzed and generalizations made.

Even though the Design #I was not fully completed, deviated from the proposed "Design Process," and resulted in a design which was far from being successful, it supports essentially the proposed "Design Process" and points out important areas which require more attention.

The steps in the proposed "Design Process" are:

I. Define list of attributes of the building.

II. Preliminary investigation.

III. Select possible designs.

March 30, 1967

IV. Investigate details of proposed design.

V. Select most suitable design.

VI. Final design.

Defining the list of attributes of the building is essentially defining the problem to be solved. This is determining the functions to be performed by the building and the limitations placed upon it by the owner.

Preliminary investigation involves setting the detailed objectives or goals to be accomplished. Once the problem is defined, then it is necessary to develop detailed goals which must be met.

Selecting possible designs is the step of major importance which was not fully considered in Design #I. This is the step in which the alternative solutions are established. Many possible designs could accomplish the objectives established in the preliminary investigation. In Design #I not enough time was spent in this phase. The design moved too quickly from the statement of the problem to the final solution only to find that another solution not considered might have been more successful. This points out the need to consider many possible designs and not to be limited to a preconceived concept or a pet design. One method to avoid this is to define the variables, such as plan form, material, and structure, and then to list various types of these variables, and to consider all the possible combinations. The point is that a possible design will never be considered unless it is proposed. This step is the point at which the creativity and imagination of the architect and engineer is most heavily called upon.

March 30, 1967

Investigation of proposed design is the comparison of the alternative designs. This was entirely lacking in Design #I. Only one solution was proposed so there were no alternatives to consider. To evaluate the alternative solutions properly, how well each alternative satisfies the goals established in the preliminary investigation must be considered.

Selecting the most suitable design is deciding on the final solution. Deciding on the most suitable design involves evaluating the importance of the various goals set in the preliminary investigation, and then determining which alternative design best satisfies all the goals. This involves the owner since it is he who must set the weighting or priority of the goals. This involves determining whether availability of parking is more important than preserving the natural setting, for example.

The final design involves working out the details of the design chosen in the steps above.

These steps in the "Design Process" are interrelated and overlapping. The Design #I points out that each succeeding step in the process tends to add information and clarify the previous steps. For example, the goals set in the preliminary investigation may be modified and revised after the proposed designs are analyzed and their performance determined. Also, other alternative designs may be brought out by evaluating the previously proposed alternatives.

William B. Hendrick
March 23, 1967

In retrospect the pilot Architecture 540 research program seems to have deficiencies which lie in four categories. These are: faults of the researchers, of the administrators, of the program itself, and of the design procedure itself.

In reviewing the schedule and work of the researchers, the major fault seems to be in the fact that the researchers did not work fast enough. The reasons for this are numerous. Due to this being the initial program, Messrs. Nelson Williams and Hendrick were undoubtedly confused about the program objectives, and about the methods by which these objectives were to be accomplished. It seemed that the primary goal was to materialize and utilize a design procedure which would be universal in application. If so, this was not the ultimate result of the research. In order to more completely analyze the work done last quarter, it will be necessary to repeat the process, and to speed up the decision making. The researchers recorded their design procedure, and then attempted to design a suburban religious facility utilizing the design procedure agreed upon. However, by the time the design was materialized, there was not enough time to analyze both the design and the procedure and to revamp where necessary.

The bad timing on the part of the researchers is due mostly to their methods. In my opinion the methods were not analytical enough. In other words, we did not weigh the relative advantages and disadvantages of several structural systems in order to determine the one best applied in the church program. Once a preliminary design was conceived, it was immediately agreed upon, and was not questioned further. In future

research of this nature, it would definitely be better to analyze several designs, and use the analysis to reach agreement as to which design solution best satisfies the program.

Partial fault of the research program lay also in the administrators. This again may be blamed on the fact that the research was a pilot program, and could not be analyzed in terms of previous research. The administrators, in my opinion, were at times not sufficiently familiar with the problem being designed. For example, when J. N. Smith was presented with the preliminary design, he immediately questioned the provision of 3000 square feet of choir practice and for a church of 400 seats. Mr. Smith was critical of the provision until it was pointed out that the design criteria required this excessive amount of space be devoted to choir practice. Mr. Smith's criticism of the space requirement is not unfounded, because the 3000 square feet is an unreasonably large figure. However, this illustrates that the fault should have been found and compensated for before the program was issued to the researchers. It is in this manner that I think the administrators were at fault and not sufficiently familiar with the design problem.

This leads us to the third point of criticism of the research program, the fault found in the design program itself. As has already been mentioned, the space requirement for the choir practice area was unrealistic. The program for the research was not written specifically to aid in the research, but rather was selected from a voluminous file of previously used student design programs. Theoretically, of course, any design program should have worked. However, the one selected was

not well adapted to the research, since it was rather nebulously and poorly written. One way, in my way of thinking, that the program could have been improved is to have provided a maximum budget limitation. It is possible (although not determinable at this time) that the provision of a budget limitation for the project might have been helpful in forcing an earlier selection of structural system and materials to be used in the church. Certainly at least a few systems could have been eliminated immediately, such as pre-cast concrete panels.

The design procedure presents the last source of problems in the research program. It would seem that the design procedure utilized did not allow for enough variables. I think however, that the procedure could have been incorporated as a cyclical process. In such a procedure, the last step (that of analysis of the solution) allows for re-evaluation of the design, and modification if the design does not best suit the program. This again would imply that the researchers did not work quickly enough to repeat the process several times. Had the procedure been speeded up, several designs could have been analyzed, and a more desirable solution possibly reached.

Finally, I do not think that the research done was a total waste. Certainly it will prove to be a valuable standard to which we will be able to compare research done in the future.

APPENDIX III

A PARKING GARAGE

Appendix III contains a statement of the second design problem, the proposal design process, and the documentation of the design, also it contains comments which were made as the design progressed.

PARKING GARAGE

Design a parking garage to accomodate 500 cars for the central business district. The garage is to be designed in such a way as to permit the lowest parking rate and to return to the owner 10 per cent of his invested capital annually.

Use the following data:

amortization period	20 years
interest rate	$6\frac{1}{2}\%$
mortgage	80%
land cost	$100,000
taxes	$1\frac{1}{4}\%$ of real value
insurance	$1\frac{1}{2}\%$ of real value

The site is rectangular, 190' N-S, and 245' E-W. It is bordered on the N and E sides by major streets.

C. Nelson Williams
April 4, 1967

STEPS IN DESIGN PROCEDURE

1. Define problem.

2. Determine list of attributes.

3. Select possible design.

4. Investigate details of proposed design or comparison of alternatives.

5. Select most suitable design.

6. Final design.

C. Nelson Williams
April 4, 1967

DEFINE PROBLEM

Design a parking garage to accommodate 500 cars for the central business district to return to the owner 10 per cent of his invested capital annually with the lowest parking rate.

The garage must fit on the lot shown and meet the parking demand for that section of the central business district.

C. Nelson Williams
April 5, 1967

COMMENTS

The list of attributes determines the final design. They must be defined by the owner with the help of the architect and engineer. The design of the building can not be separated from the owner who establishes the features which he wants his building to provide.

C. Nelson Williams
April 4, 1967

COMMENTS

Preliminary Comparison of Alternatives and Detail Comparison of the Alternatives

Preliminary comparison is not as deep a comparison as the detailed comparison. First a large number of alternatives are compared by a preliminary comparison to eliminate the alternatives that are not suitable even at the preliminary stages. Then as the alternatives become fewer and fewer the comparison must become more and more detailed. This leads to a cyclic application of steps:

3. Select possible design.

4. Investigate details of proposed design or comparison of alternatives.

5. Select most suitable design.

This starts with the most general design including many alternatives and then by repeated application of the three steps leads to a detail comparison of only a few alternative. Therefore, the design is refined by repeated application of the three steps above.

April 4, 1967

CYCLE NO. 1

(CONCEPT DECISION NO. 1)

Select between single layer and multi-layer structures.

500 spaces required

Estimate 300 ft^2/space

Required area = (500 spaces) (300 ft^2/space) = 150,000 ft^2

Area of single layer = 46,500 ft^2

Therefore multi-layers required

Approximate number of parking layers = $\frac{150,000}{46,500} = 4$

C. Nelson Williams
April 5, 1967

CYCLE NO. 2

(CONCEPT DECISION NO. 2)

Select Possible Designs

Types of Garages (Multi-level facilities)

1. Mechanical parking installation.
2. Underground garages.
3. Ramp type garages.

C. Nelson Williams
April 5, 1967

FIRST PRELIMINARY COMPARISON OF ALTERNATIVE

1. Mechanical Parking Installation

This type of parking garage has the advantage that it can be erected on a small or irregularly shaped plots. It can be used to advantage on small lots which prohibit the use of long ramps. With larger units the process of parking and retrieving a car requires a fairly long time. This requires a space to act as a reservoir for the peak parking hours. This requires space and eliminates part of the space advantage.

The mechanical equipment is fairly expensive. Also the maintenance and operating cost is fairly high. Therefore, it is concluded that this type of garage is suited best to closely built up, narrow lots.

2. Underground Garages

An underground garage with several basements is much more costly than a parking facility of equal capacity above ground. Underground garages with several basements will, therefore, only be economical in closely built-up areas where the land values are very high. In such

circumstances, the land can in fact only be utilized to the fullest if the garage is placed in the basement of a hotel, office building, or other type of building. The planning of an area may make it necessary to put the parking underground in order not to disturb a park or other facility.

3. Ramp Type Garages

Ramp type garages require sufficient space for the inclined ramps. A ramp garage requires a plot of certain minimum size which roughly amounts to 100' X 100' (10,000 ft^2).

When the space is available, the ramp type garage will be the most economical to build and operate.

Reference: Metropolitan Parking Structures.

SELECT MOST SUITABLE DESIGN

List of Attributes	Mechanical Type	Underground Type	Ramp Type
Provide 500 spaces			
Cost	Expensive	Expensive	Least
Circulation			

Since the area of the site provides no limitations, and there is no special planning or other consideration that would provide a limitation on the type, the ramp type of structure is selected for further investigation.

Use

Ramp type.

April 5, 1967

CYCLE NO. 3

(CONCEPT DECISION NO. 3)

Select Possible Ramp Type Garage

Types of ramp garages.

1. Straight ramps between full-level parking floors.
2. Helical ramps between full-level parking floors.
3. Ramps between split level floors.
4. Ramped floors.
5. Combinations.

Variation in ramp garages.

1. Attendant parking.
2. Customer parking.

BACKGROUND DATA

Story Height

Floor to ceiling = $7\frac{1}{2}$'

3 Basic Dimensions of Any Parking Layout

1. Length and width of car stall.
2. The width of access road.
3. Angle between car stall and access road.

Length and Width of Car Stall

Length = 19'

Width = 9' range 8' to 10'

Access Road Width

Related to stall width; with wider the stall it is possible to use a somewhat narrower access road.

Width = 11' for one way
Width = 24' for two way } use same dimension for ramp

Angle Between Stall and Access Road

90° or 60°

Reference: Parking -

April 12, 1967

COMMENT

Cycle III has gone into too much detail. The general field of parking structure must be limited much further before a detailed study of layout and circulation is considered.

First, the general types must be compared to determine which will best meet the list of attributes before the details of this type is worked out.

This can be done by using representation data for the different types of garage facilities in order to cycle through the three steps. The major objection to this is it limits the designer to only consideration of known systems for which data is available. This limits design to the evaluation of a few known systems to determine which will best carry out the prescribed function defined in the list of attributes. For this problem, this seems to be the best course of action. The problem is to design a parking garage which will make a certain amount of money per year for the owner while charging the least for each parking space. The owner is concerned about knowing the cost of the structure

and how much it will yield. He is not concerned with experimenting with new types of structures in which the uncertainties involved will not let him adequately predict its cost and earning potential.

April 13, 1967

DEFINE PROBLEM

In order to design a parking garage the basic information concerning the existing and potential parking demand must be known. This is part of defining the problem. Answers must be sought to:

What type of parkers will be expected to use the garage?

How many parkers of each type?

What are their time-characteristics?

Answers to these and other questions will vary from city to city and from location to location within the city. There is no precise easy way to make such an evaluation. The evaluation may be made by consulting existing parking surveys and the demand characteristics of garages of similar locations.

The problem calls for "a parking garage to accomodate 500 cars for the central business district." This says very little about the type of parkers or their time characteristics. Therefore, to continue with the problem, the following assumptions are made.

The garage is assumed to serve a large variety of patrons including shoppers, businessmen, hotel guests, and theater goers. This limits and defines the parking demand of the garage.

An example of similar location and patrons is given in Traffic Design of Parking Garages. The traffic characteristics of the garage are:

Garage "C" Eno Foundation

Nominal stall capacity = 525

Turnover = $\frac{527}{425}$ = 1.24

Peak Flows

Inbound = 115 cars/hr. or 27%

Outbound = 167 cars/hr. or 39%

Average Flow

Inbound = 70 cars/hr. or 16%

Outbound = 83 cars/hr. or 20%

Assumed for Design

Nominal stall capacity = 500 cars

Peak Flows

Inbound @ 27% = 135 cars/hr

Outbound @ 39% = 195 cars/hr

Average Flow

Inbound @ 16% = 80 cars/hr

Outbound @ 20% = 100 cars/hr

Turnover = 1.25 $\frac{\text{full garage}}{\text{day}}$

Important characteristic of this type of location:

1. Continuing demand for 15 hours.
2. Importance of long-term parkers. These represent 30% of total volume and arrive in the morning. Businessmen.
3. There is an evening peak due to theater goers.

ATTENDANT VS. SELF-PARKING

Area Required

Self Service - 300 ft^2/stall

Total = (300 ft^2/stall) (500 stalls) = 150,000 ft^2

Attendant - 240 ft^2/stall

Total = (240 ft^2/stall) (500 stall) = 120,000 ft^2

Construction Cost $5.00/$ft^2$

Self Service

Total Cost = ($5.00/$ft^2$) (1 0,000 ft^3) = $750,000

Attendant

Total Cost = (5.00/ft^2) (120,000 ft^2) = $600,000

Employees

Self-Service

7 = 1 manager + 2 shifts of 3 per shift

Attendant

7 +

Assume

10 cars/attendant/hr

$$\text{No attendants} = \frac{(195 \text{ cars/hr})}{10 \text{ cars/attend/hr}} = 19.5 \text{ Attendant}$$

7 + 20 = 27 attendants

27 = 1 manager + 2 shifts of 13 per shift

P = ($700,000) (.80) = 560,000.00

I = 6.5%/year

$$PI\ \Sigma^{19}\left(1 - \frac{k}{20}\right) = (.065)\ (\$560{,}000)\ (10.50) = \$392{,}000$$

$k = 0$

Amount of interest per year = $\frac{\$392{,}000}{20\ \text{yrs.}} = \$19{,}600$

Total of principal plus = \$19,600 + 28,000

Interest per year = \$47,600

April 17, 1967

Costs:

	Att. Park	Self-Park
Taxes: 1.25% of $850,000 (a) =		$10,625
1.25% of $700,000 (b) =	$8,750	
Insurance: 1.5% of $850,000 =		12,750
700,000	10,500	
Mortgage: 6.5% of $680,000		52,250
Paid per year P + I	47,600	
Maintenance & Overhead:		
Eno Foundation ($2.80/space) (500)		1,400
Table VIII-6 ($2.80/space) (500)	1.400	
Salaries: a) 1 @ 3.50/hr		7,500
6 @ 1.75/hr		21,900
b) 1 @ 3.50/hr	7,500	
26 @ 1.75/hr	95,000	
Total Cost:	$170,750	$106,425

Return 10% of owners invested capital annually

Self-Service

(10%) (170,000) = $17,000

Attendant

10% (140,000) = $14,000

Real Value

Self Service

Land Value	$100,000
Garage Value	750,000
	$850,000

Attendant

Land Value	$100,000
Garage Value	600,000
	$700,000

Amount of Mortgage

Self Service

(80%) (850,000) = $680,000

Attendant

80% (700,000) = $560,000

Owner's Investment

Self Service

20% (850,000) = $170,000

Attendant

20% (700,000) = $140,000

Number of Cars-HOurs Parked per Year

$$\text{Turnover } (1.25)\ (500\ \tfrac{\text{spaces}}{\text{day}})\ (15/\tfrac{\text{hr}}{\text{day}})\ (5\ \tfrac{\text{days}}{\text{week}})\ (52\ \tfrac{\text{week}}{\text{year}}) = 162{,}500\ \tfrac{\text{car-hr}}{\text{year}}$$

Income

Owners Return = Income - Cost

Income = Cost + Owners Return

Self Service

	$106,425
	17,000
Income =	$123,425

Attendant

	$170,750
	14,000
Income =	$184,750

Parking Rate per Hour

$$\left(\frac{\text{car-hours}}{\text{year}}\right)(\text{parking rate}) = \text{yearly income}$$

$$\text{Parking Rate} = \frac{\text{yearly income}}{\text{car-hours/year}}$$

Self Service

$$\text{Parking rate} = \frac{\$123{,}425/\text{year}}{162{,}500 \frac{\text{car/hr}}{\text{year}}}$$

Parking rate = $.76 per car hour

Attendant

$$\text{Parking rate} = \frac{\$184{,}750}{162{,}500}$$

Parking rate = $1.14 per car hour

Therefore, use self service garage.

April 24, 1967

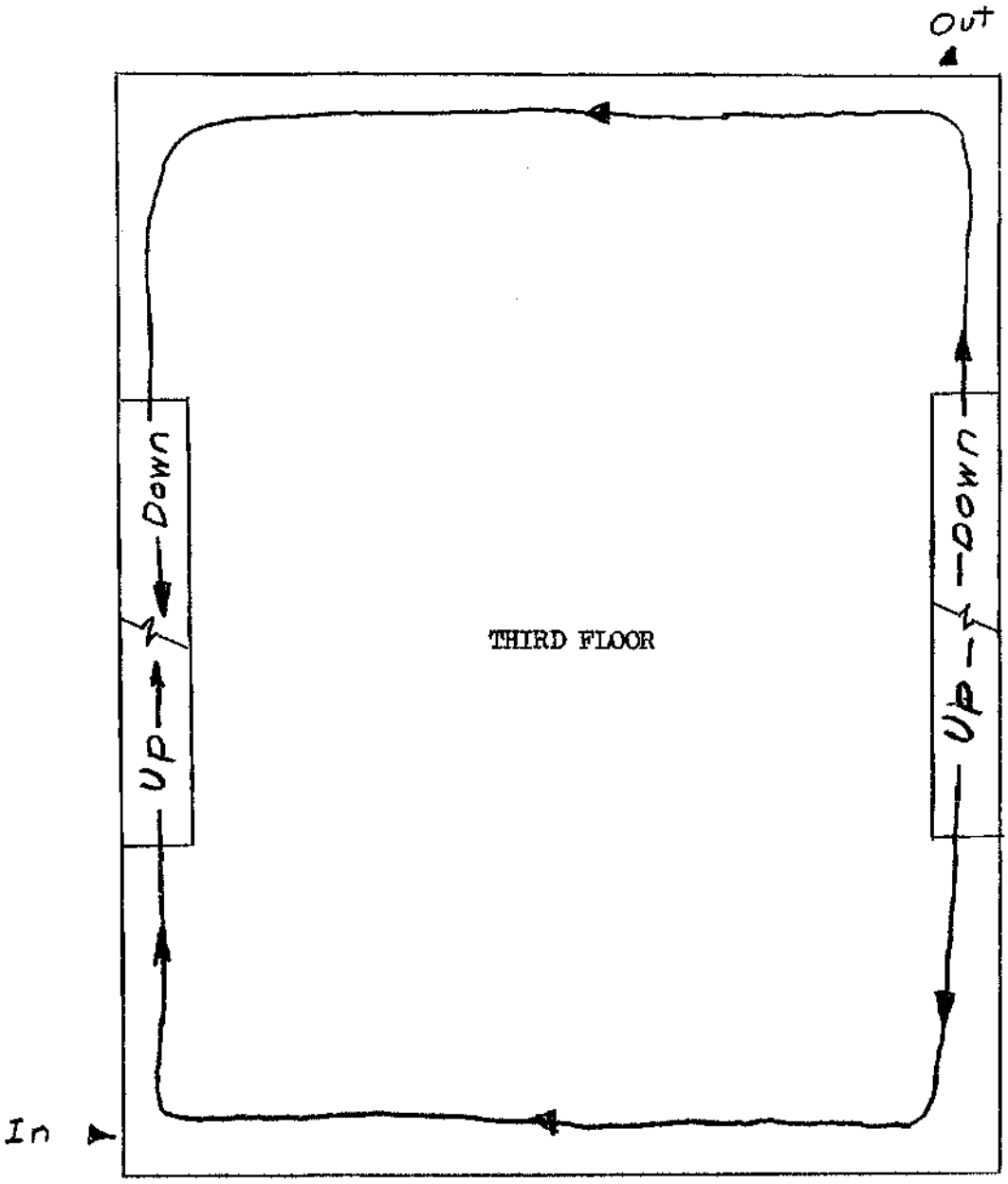
COMMENT

There seems to be two types of "Design Problems":

Problem Solving: This is optimization using criterion values and by following the steps described to decide between existing designs.

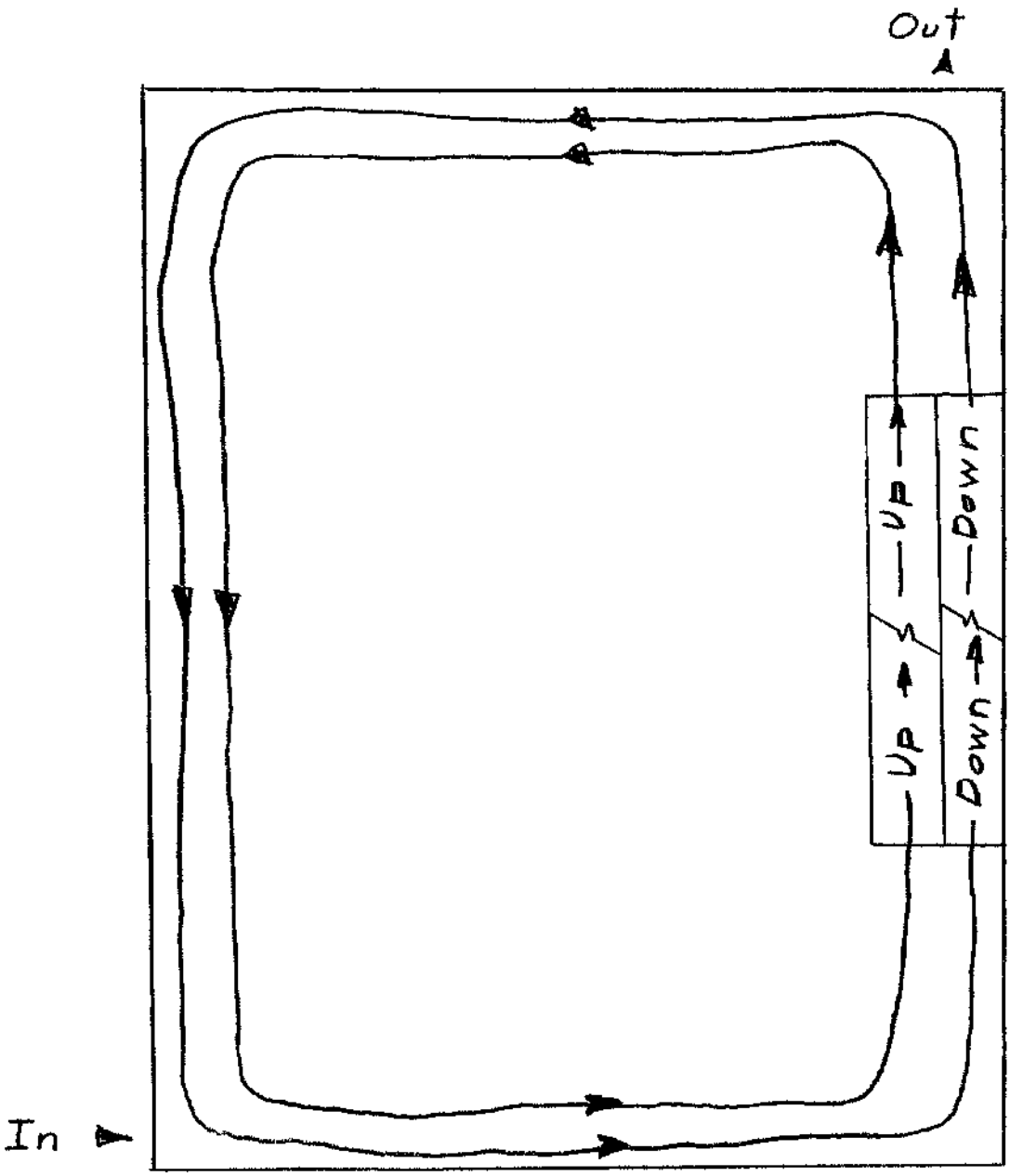
Design: Making the Form fit the context by understanding the context and creating a new form.

This parking garage seems to be a problem of optimization using the established criteria for existing designs.



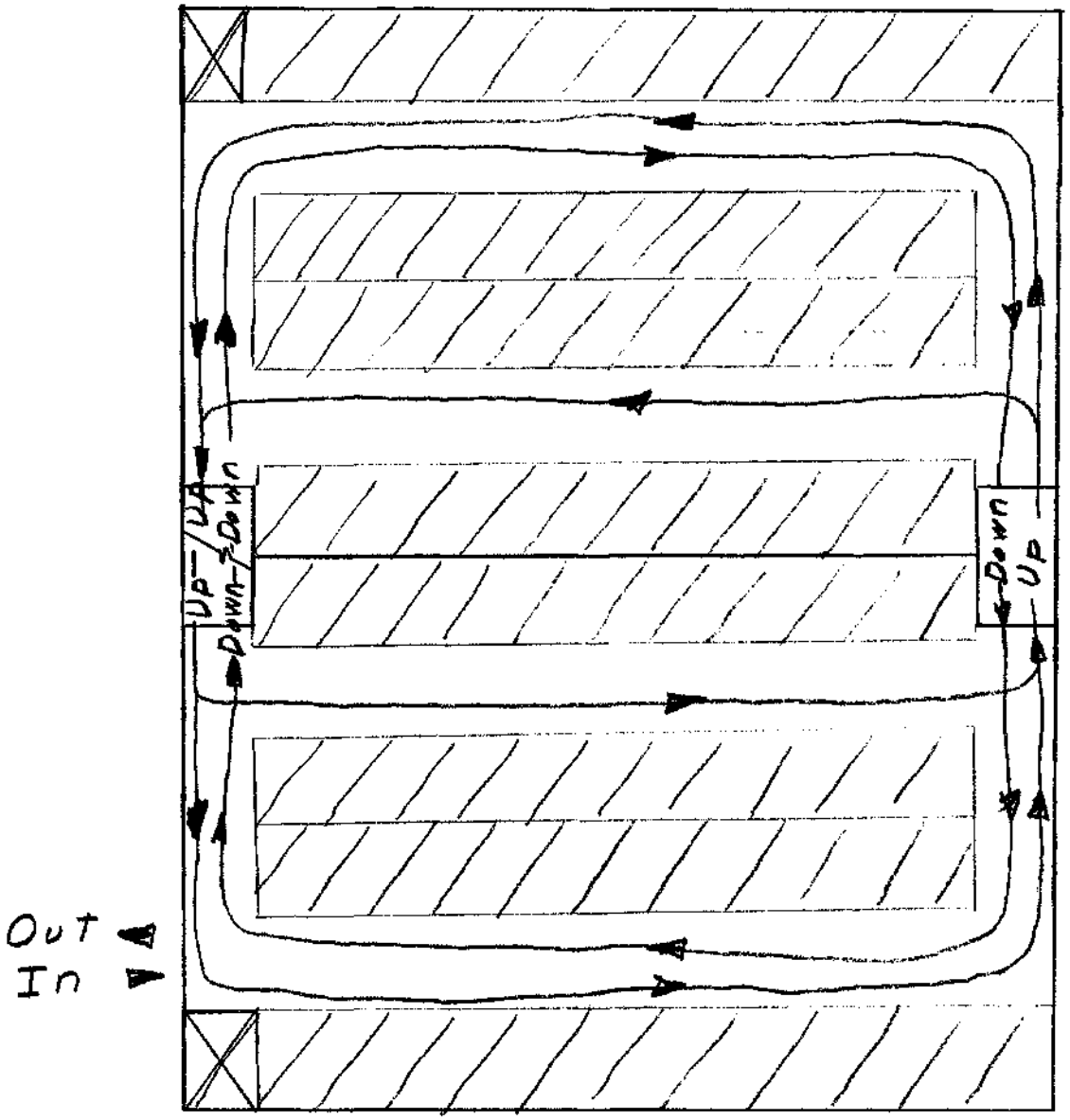
OPPOSED STRAIGHT RAMPS

1. One way ramps.
2. To exit cars must spiral down the entire system.
3. Four floors for five hundred spaces.
4. Circulation aisle and parking aisle are separated.
5. Two ninety degree turns at entrance.



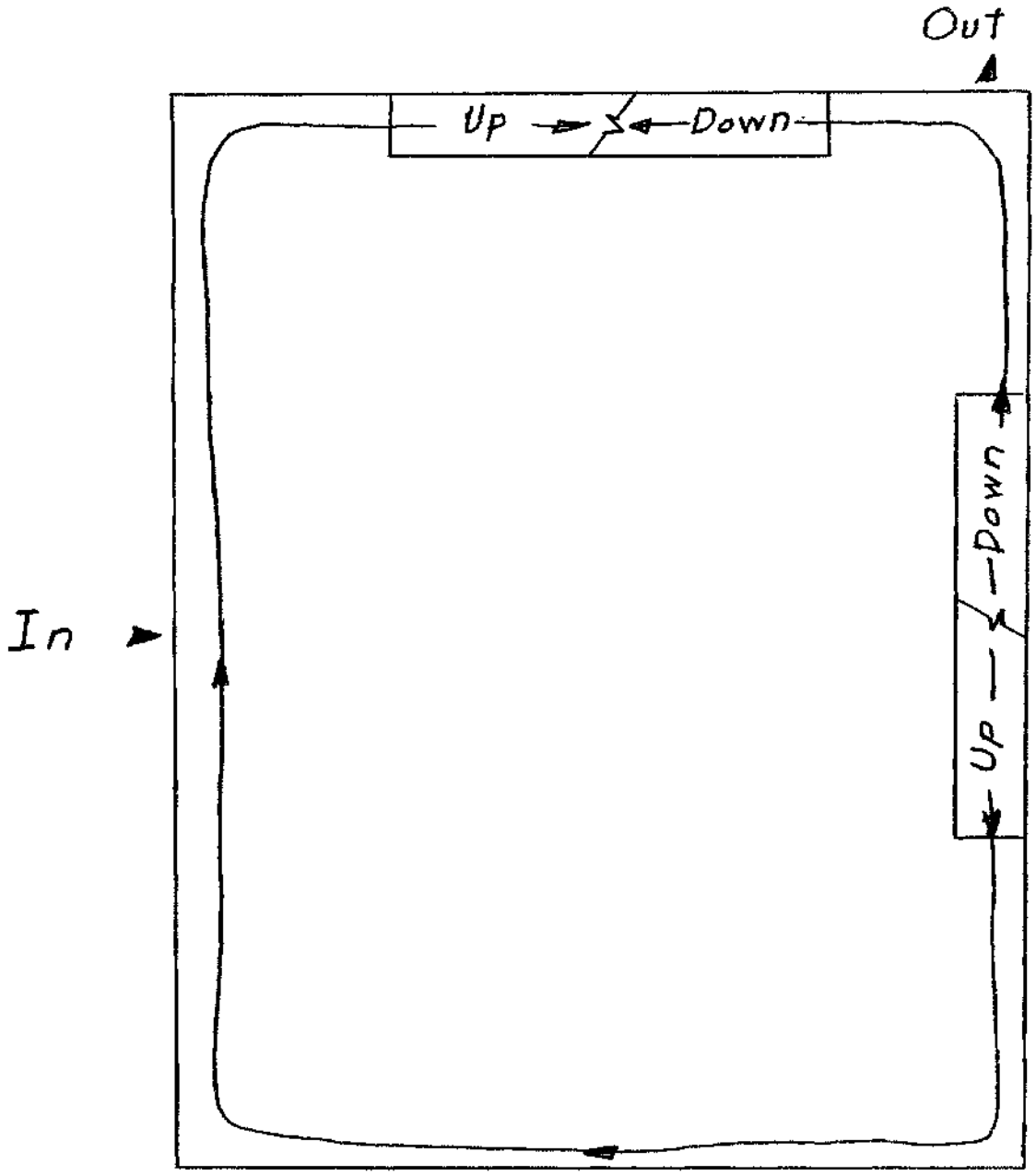
OPPOSED STRAIGHT RAMPS

1. Same as #1 except must use parking aisle for circulation.
2. One ninety degree turn to enter and exit.
3. Four floors for five hundred spaces.



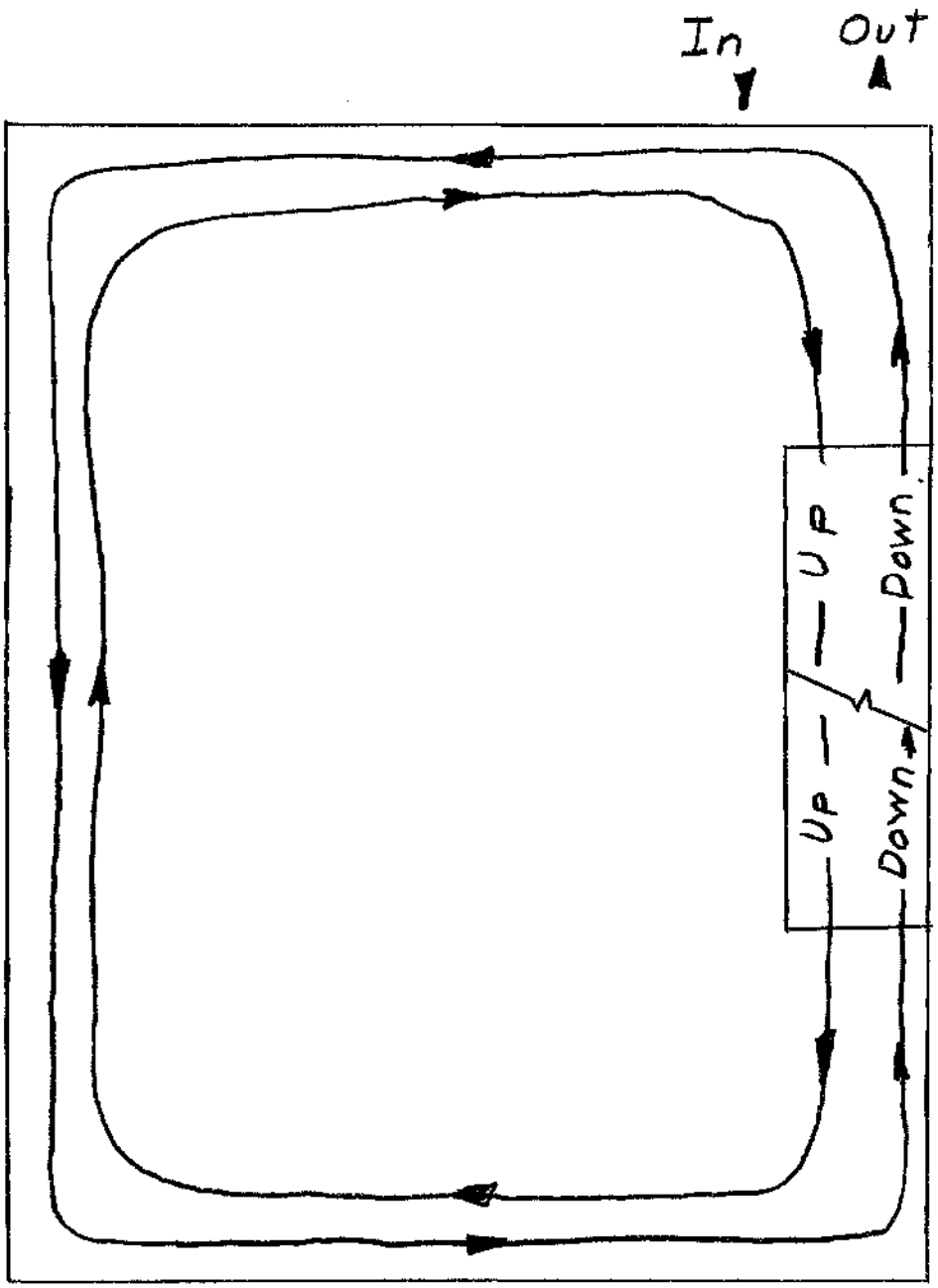
STAGGERED FLOORS

1. Two way traffic on ramp.
2. Circulation adjacent to parked cars.
3. Less area devoted to ramps and more to parking.
4. No direct exit from every floor.
5. Requires seven half stories or three and a half floors for five hundred spaces.



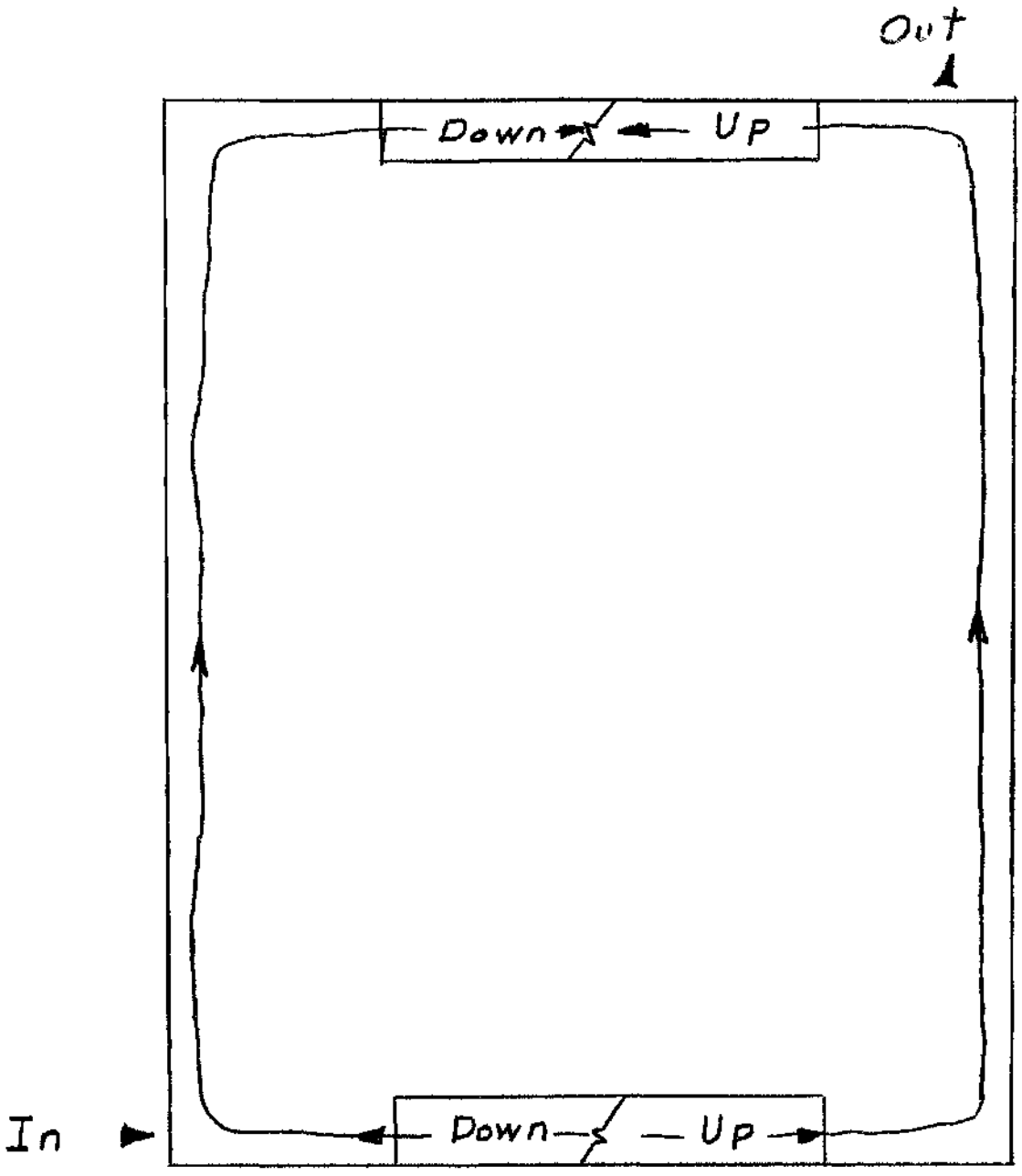
COMBINATION OF #4 AND #1

1. One way ramps.
2. To exit cars must spiral down entire system.



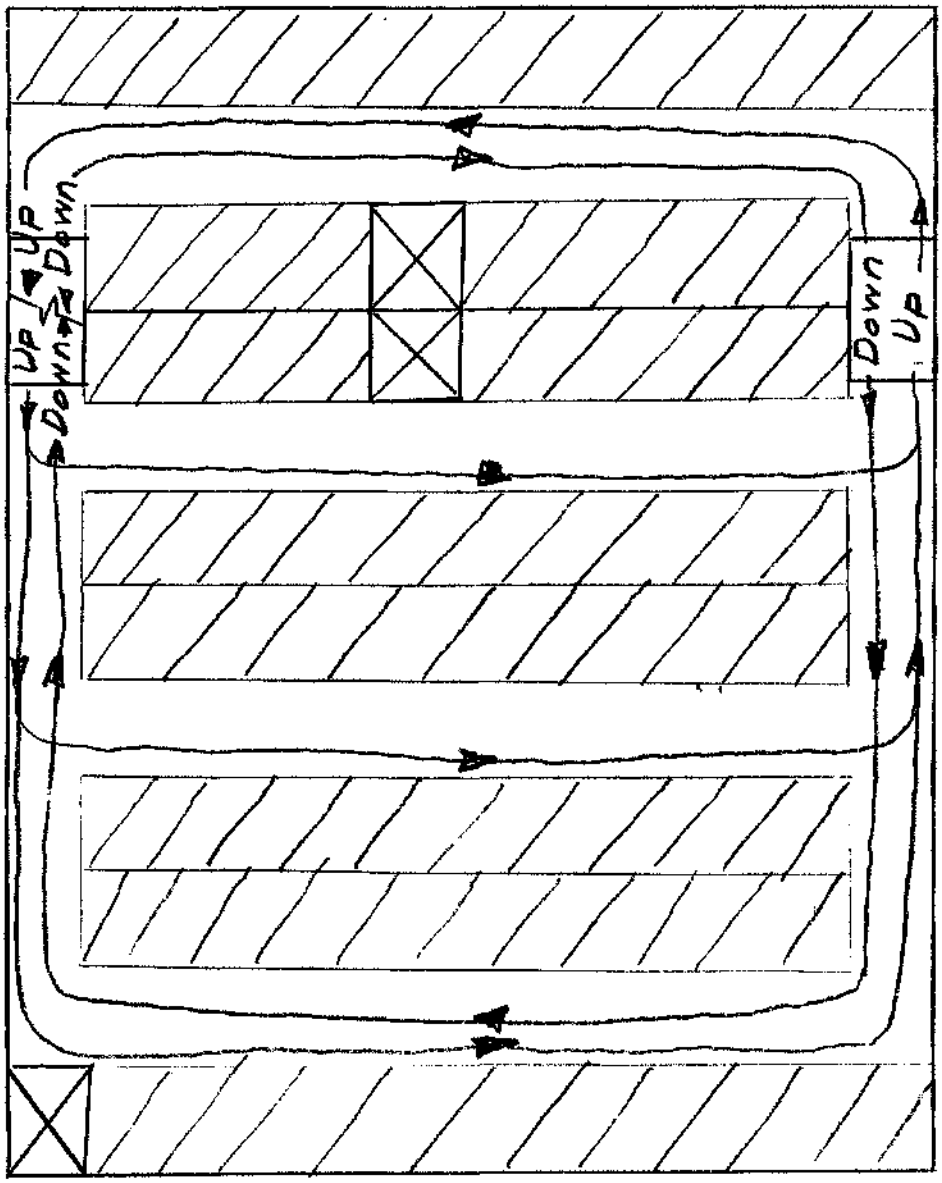
PARALLEL STRAIGHT RAMPS

1. Two way ramps and aisles.
2. Four floors for five hundred cars.
3. Conflict between entering and exiting vehicles at the entrance and at the ramp on each level.
4. One ninety degree turn to enter and exit.
5. To exit cars must spiral down the entire system.



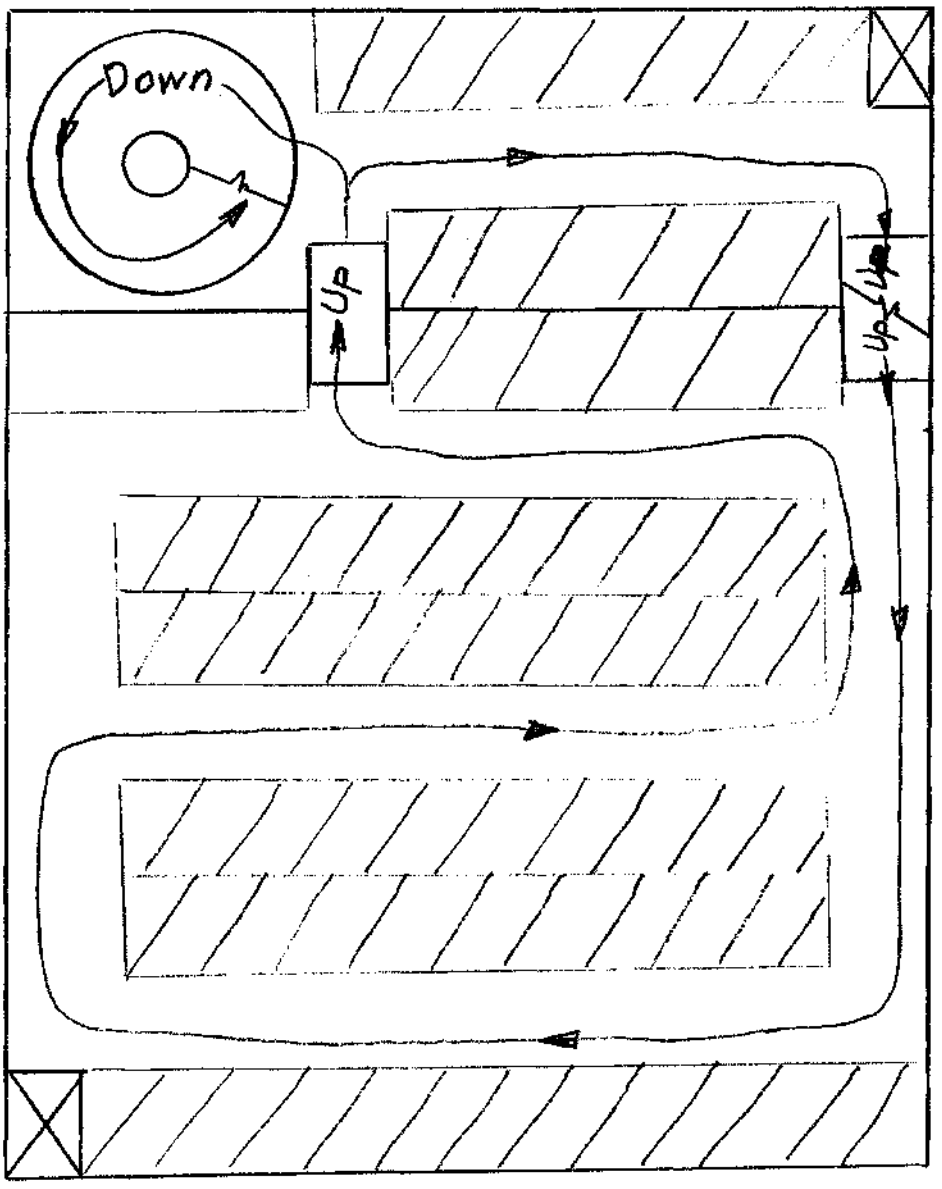
OPPOSED STRAIGHT RAMPS

1. Same as #1 except ramps on short end.
2. Four floors for five hundred spaces.



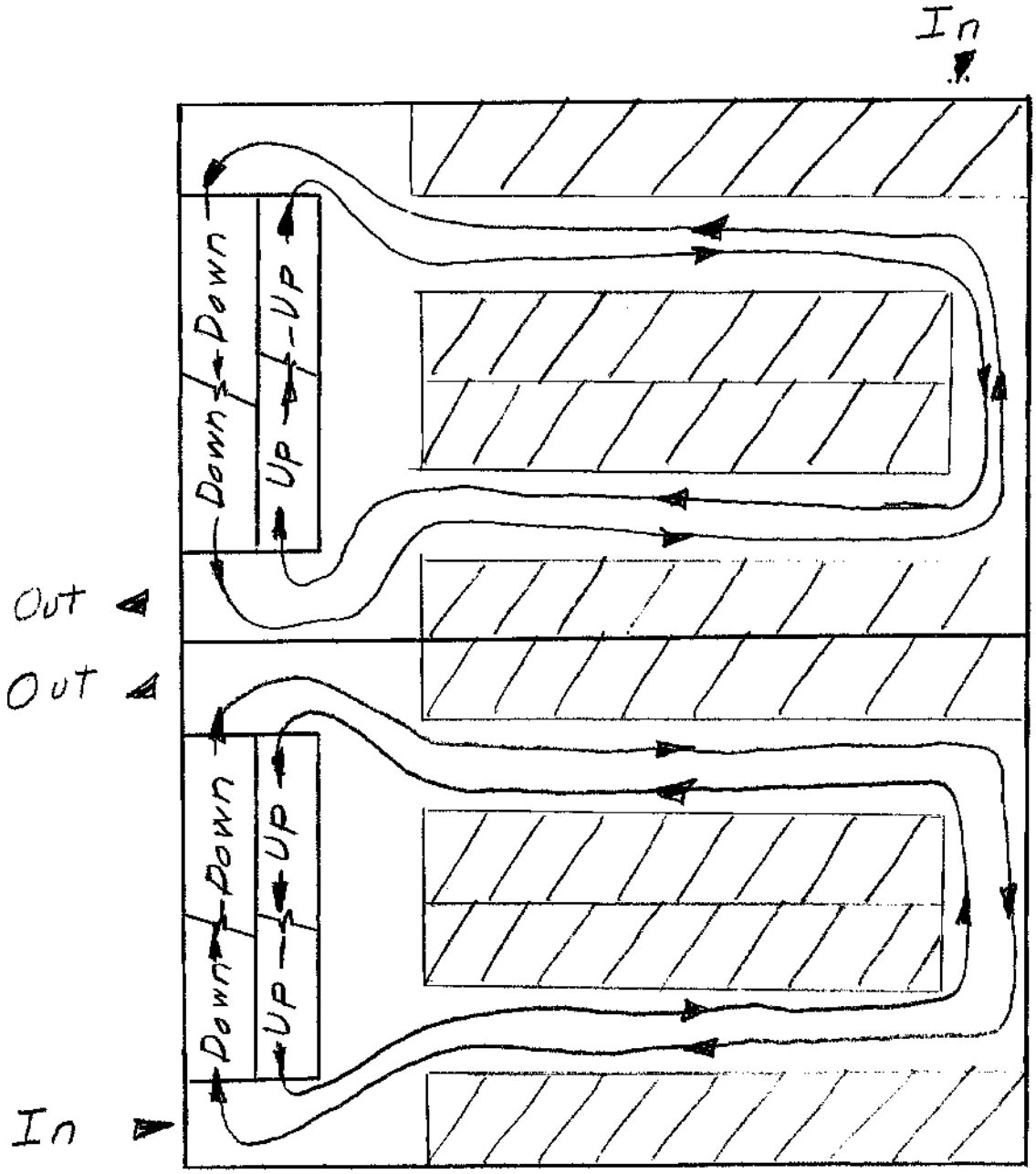
STAGGERED FLOOR

1. Same as #6 except the levels are staggered at different locations.



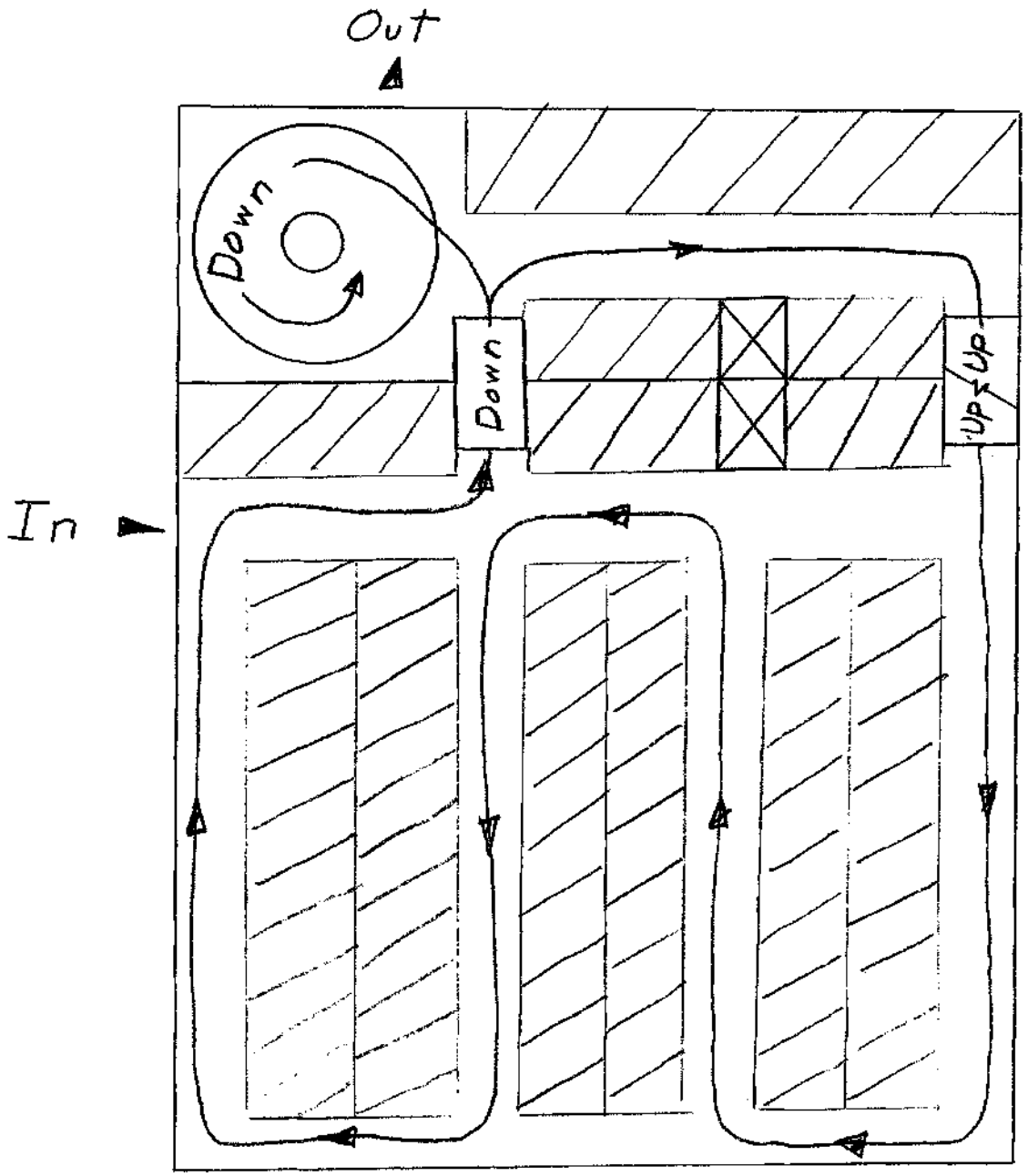
STAGGERED FLOORS AND EXIT SPIRAL

1. Same as #7 with exit spiral.
2. Direct exit from each floor without recirculating.
3. One way traffic in aisles.



TWO GARAGE COMBINATION

1. Provides more entrances and exits.



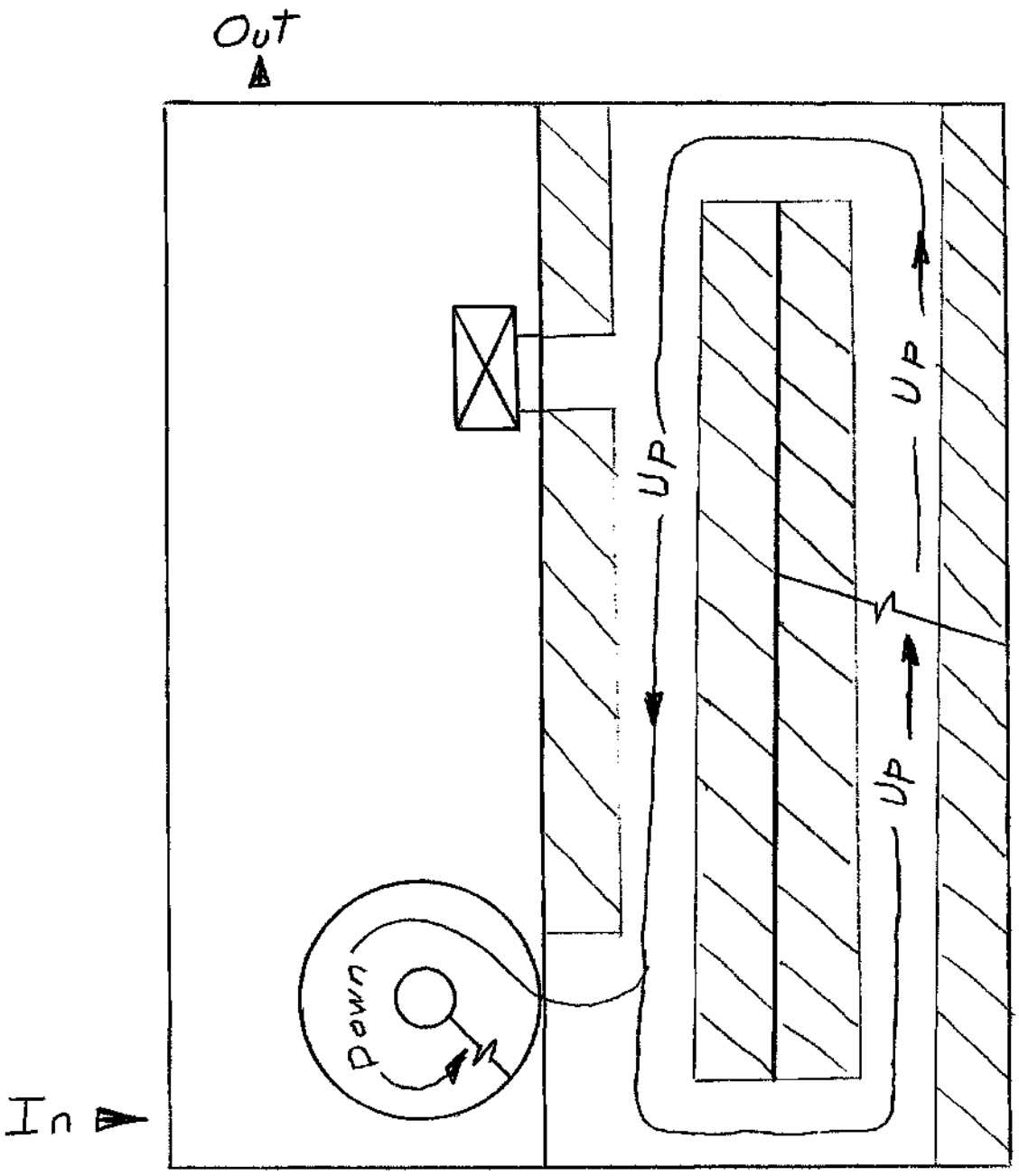
SPLIT LEVEL WITH EXIT SPIRAL

1 One way traffic in aisle.

2. Entrance and exit on different streets.

3. Direct exit to the street from any floor.

4. Five floors to provide five hundred spaces.



INCLINED RAMP FLOOR WITH EXIT SPIRAL

1. Same as #11 except seven floors required to provide five hundred spaces.

COMMENT

The last two plans were chosen because of several features. Each plan gives one way traffic in the aisle, separate entrance and exit onto different streets, and provides direct exit to the street from any floor without recirculating through the garage. These three features were chosen as very desireable and the garage was then arranged to provide them.

But the two plans are very different. The first uses the entire space and provides sufficient parking space in 5 floors. This is a more economical solution.

The second plan does not use the entire site and goes up 7 stories. But it provides an opportunity for an asethetic treatment of the grounds, and the entrance and exit ramp. The customer must get from and to his parked car. The seven floor plan would be very unattractive on this point if all customers were to return to ground level.

Other variables were introduced, by Prof. Smith. He said that it is desirable to have entrance from both streets since they were major streets. Also, he said that direct exit to the street from any floor may not be a very important consideration in a garage that is not very tall. The object is to get the cars into and out of the garage as quickly as possible without interfering with the normal flow of traffic in the street.

The important part of the problem seems to be in defining the objective to design for and their relative importance. These are the

desirable features vs. the essential features.

Define the essential features, and the desirable features. When are they considered? Are they considered at the same time? Or are they considered separately? Are there really two separate problems? One in designing the system and the other in optimizing the design? What variable are optimizes - the essential one or the desirable ones?

Ways to Achieve Good Circulation

1. One way traffic in aisle.

2. Provide direct exit to the street without recirculation on the floors.

3. Separate parking area and circulation aisle.

4. Provide one way ramps.

5. Sufficient exit lanes to prevent back up of cars in the aisles.

Ways to Provide Efficient Entrances and Exit

1. Separate entrance and exit to avoid conflicts.

2. Entrance and exit on different streets.

3. Reservoir at the entrance to separate the garage from the street traffic.

Ways to Reduce the Cost

1. Provide smallest area per parking space.

2. Keep the structure as simple and as symmetrical as possible.

3. Keep the structure as low as possible.

4. Use low cost finish material with low maintainance cost and long life.

5. Arrive at most economical structure considering both the parking module and span.

   (1) Large span for most parking space.

   (2) Short span for structural economy.

Conclusion: Use inclined Ramp with a spiral exit ramp because:

1. Circulation

   (1) Direct exit obtained by spiral ramp. This is the only means to obtain this because the length of the plot prohibits a direct inclined ramp for more than three floors.

(2) The floor is used as a ramp so it eliminates the extra space.

(3) Provides the simplest pattern for the customer to follow.

CYCLE NO. 5

(CONCEPT DECISION NO. 5)

Alternative I

1. No separate entrance and back up lanes.
2. Does not use the entire land available.
3. Only one entrance.

Alternative II

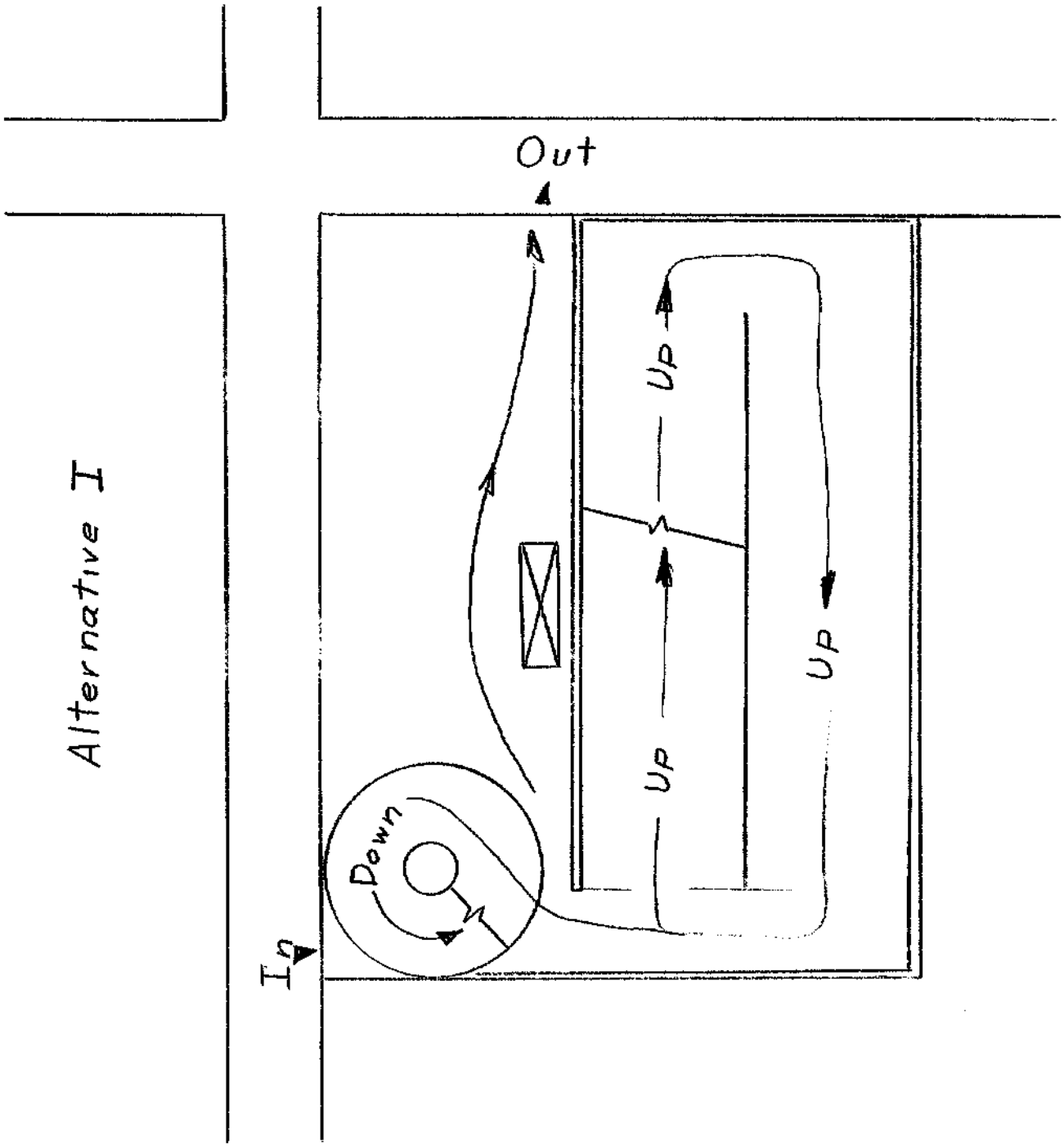
1. No back up lanes for exit.
2. Only one entrance.
3. Potential conflict between drivers at entrance to exit spiral.

Alternative III

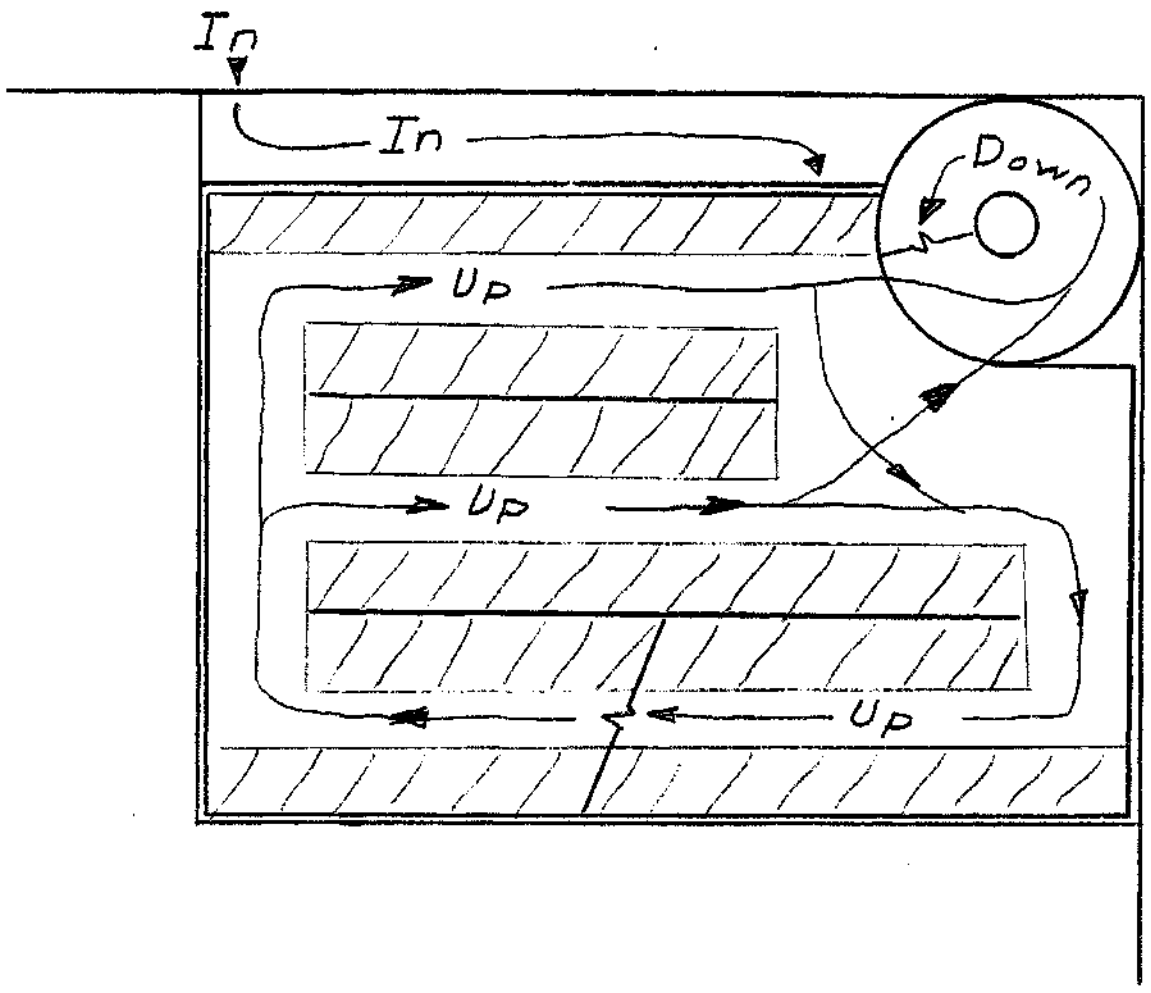
1. No simple circulation pattern for the spiral in the center.

Alternative IV

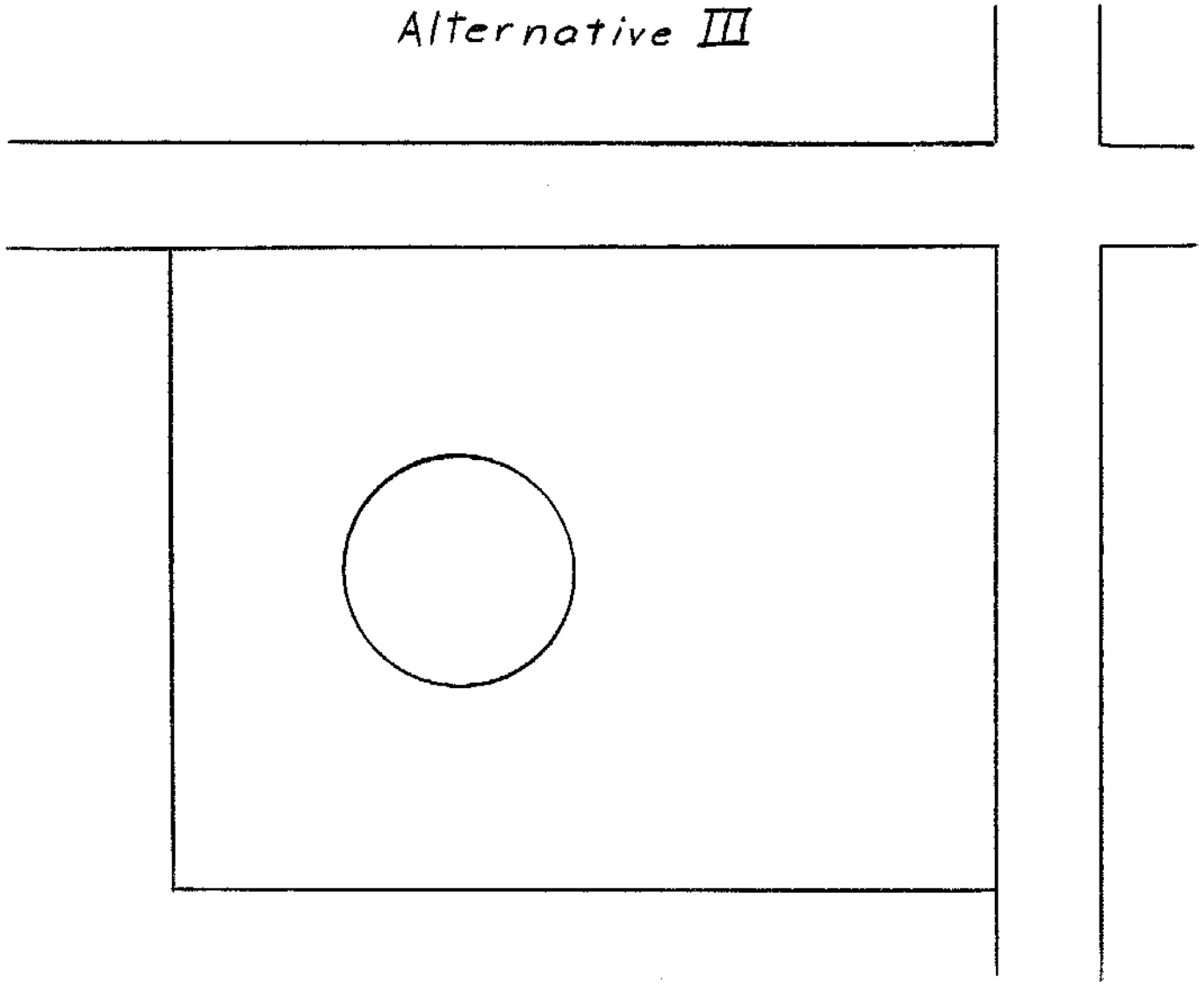
1. Two entrances but only one exit.


Alternative I
Out
In
Down
Up
Up
Up

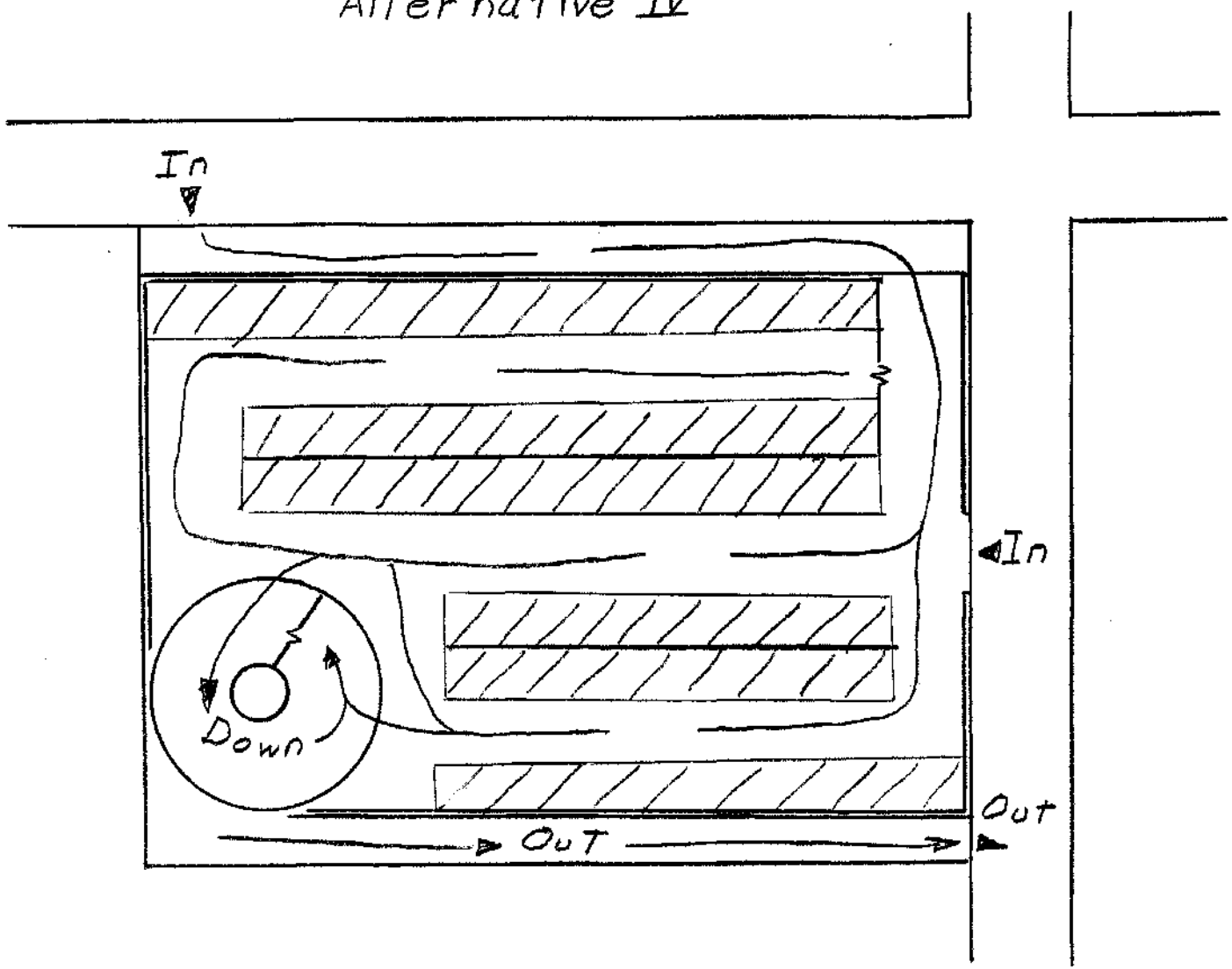
Alternative II



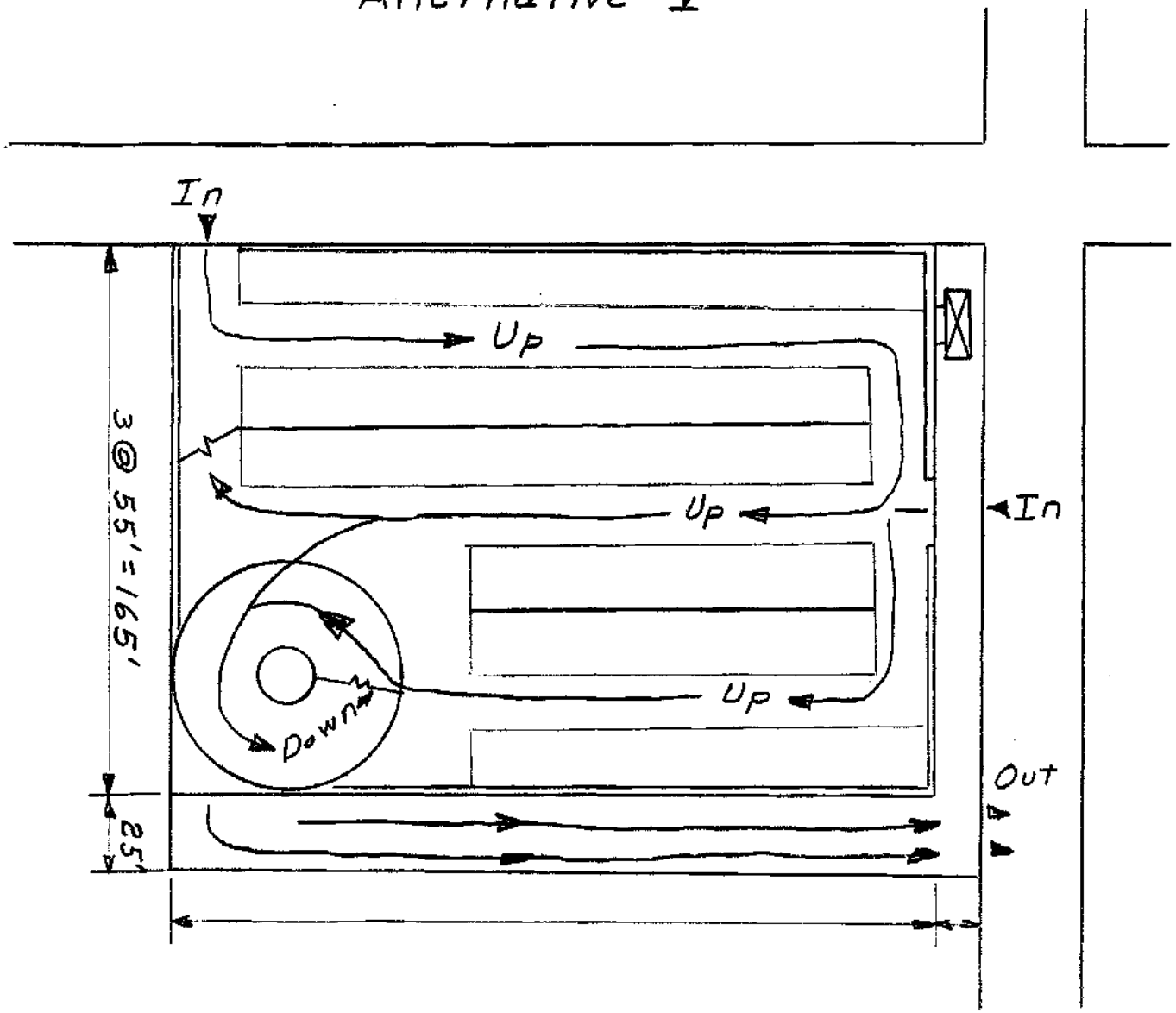
Alternative III



Alternative IV



Alternative V



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